Knowledge Base Methodology - Methodology for First Engineering Script Language (ESL) Knowledge Base

Kumar Peeris
Michel Izygon

Barrios Technology, Inc.

December 1, 1992

Cooperative Agreement NCC 9-16
Research Activity No. SR.02

NASA Johnson Space Center
Information Systems Directorate
Information Technology Division

ricis

Research Institute for Computing and Information Systems
University of Houston-Clear Lake

DRAFT INTERIM REPORT

The RICIS Concept

The University of Houston-Clear Lake established the Research Institute for Computing and Information Systems (RICIS) in 1986 to encourage the NASA Johnson Space Center (JSC) and local industry to actively support research in the computing and information sciences. As part of this endeavor, UHCL proposed a partnership with JSC to jointly define and manage an integrated program of research in advanced data processing technology needed for JSC's main missions, including administrative, engineering and science responsibilities. JSC agreed and entered into a continuing cooperative agreement with UHCL beginning in May 1986, to jointly plan and execute such research through RICIS. Additionally, under Cooperative Agreement NCC 9-16, computing and educational facilities are shared by the two institutions to conduct the research.

The UHCL/RICIS mission is to conduct, coordinate, and disseminate research and professional level education in computing and information systems to serve the needs of the government, industry, community and academia. RICIS combines resources of UHCL and its gateway affiliates to research and develop materials, prototypes and publications on topics of mutual interest to its sponsors and researchers. Within UHCL, the mission is being implemented through interdisciplinary involvement of faculty and students from each of the four schools: Business and Public Administration, Education, Human Sciences and Humanities, and Natural and Applied Sciences. RICIS also collaborates with industry in a companion program. This program is focused on serving the research and advanced development needs of industry.

Moreover, UHCL established relationships with other universities and research organizations, having common research interests, to provide additional sources of expertise to conduct needed research. For example, UHCL has entered into a special partnership with Texas A&M University to help oversee RICIS research and education programs, while other research organizations are involved via the "gateway" concept.

A major role of RICIS then is to find the best match of sponsors, researchers and research objectives to advance knowledge in the computing and information sciences. RICIS, working jointly with its sponsors, advises on research needs, recommends principals for conducting the research, provides technical and administrative support to coordinate the research and integrates technical results into the goals of UHCL, NASA/JSC and industry.

RICIS Preface

This research was conducted under auspices of the Research Institute for Computing and Information Systems by Kumar Peeris of the University of Houston-Clear Lake and Dr. Michel Izygon of Barrios Technology, Inc. Dr. Rodney L. Bown served as the RICIS research coordinator.

Funding was provided by the Information Systems Directorate, NASA/JSC through Cooperative Agreement NCC 9-16 between the NASA Johnson Space Center and the University of Houston-Clear Lake. The NASA research coordinator for this activity was Ernest M. Fridge III, Deputy Chief of the Software Technology Branch, Information Technology Division, Information Systems Directorate, NASA/JSC.

Research Activity Number:	SR.02
Subcontract Number:	103
Task Deliverable Number of Specific Reference from SOW:	2
Title of Task:	Knowledge Base Methodology Methodology for first Engineering Script Language (ESL) Knowledge Base
Subcontractor:	Barrios Technology Inc.
Cooperative Agreement Number:	NCC-9-16
Principal Investigator:	Dr. Michel E. Izygon
NASA Technical Monitor:	Ernest M. Fridge III
Type of Report:	Draft Interim Report
Period Covered by Report:	06/01/92 to 12/01/92
Due Date:	December 31, 1992

Delivered To: RICIS Document Control Department
Box 444
University of Houston-Clear Lake
2700 Bay Area Boulevard
Houston, Texas 77058-1096

*** FIRST DRAFT ***

INTERIM REPORT: KNOWLEDGE BASE METHODOLOGY - METHODOLOGY FOR FIRST ENGINEERING SCRIPT LANGUAGE (ESL) KNOWLEDGE BASE

by
Kumar Peeris (UHCL) and Michel E. Izygon (Barrios)

Reuse : Background and concepts.

Software Reuse is one of the technologies that is currently presented as being able to solve the so-called "Software Crisis". In this section, we will describe some of the key concepts of this technology, the different approaches to reusability, some of the issues related to it, and we will try to present how the Engineering Script Language (ESL) implement the reuse paradigm.

Reuse Concepts

The primary goal of reusing software components is that software can be developed faster, cheaper and with higher quality. Though, reuse is not automatic and can not just happen. It has to be carefully engineered. For example a component needs to be easily understandable in order to be reused, and it has also to be malleable enough to fit into different applications. In fact the software development process is deeply affected when reuse is being applied. During component development, a serious effort has to be directed toward making these components as reusable as possible. This implies defining reuse coding style guidelines and applying them to any new component to create as well as to any old component to modify. These guidelines should point out the favorable reuse features and may apply to naming conventions, module size and cohesion, internal documentation, etc... . During application development, effort is shifted from writing new code toward finding and eventually modifying existing pieces of code, then assembling them together. We see here that reuse is not free, and therefore has to be carefully managed.

Approaches to Reuse

There are two different approaches to reusing software components: Adaptive Reuse and Compositional Reuse. Their characteristics are as follow:

- Adaptive Reuse

With this approach,
components are templates or paterns and are changed each time they are used.

- Compositional Reuse

components are atomic and don't change when they are used.

Issues / Dilemas

The operational problems of reusability are the following:

- finding components
- understanding components
- modifying components
- composing components

When a programmer has to develop a piece of code, the first thing he does is to look in the library of available components to check if there is one that matches his needs. This search process needs to be able to find not only the exact match, but also the "close enough" type of components if the ideal one does not exist. The difficulty of this step is directly linked to the breadth of the library of components. The more specific are the components, the more numerous they will be in the library, and the more difficult it is to find the appropriate one. This aspect of the reuse process is dealt with library systems.

Understanding a component is the next step the programmer will go through, in order to be able to use properly the component he found during the search process. If modifications are necessary, i.e. if the component does not match exactly the need of the programmer, the understanding is even more important as he will need to enter into the code and change it. For this understanding process to be succesful, there needs to be a lot of emphasis on documentation during design and coding of any reusable component.

Modification of components is the step that seems to be the less automatizable. The programmer has to do his work at customizing the component to his needs. The issue that is related to this step is that we can foresee that many components may be spawned out of a common root component in order to customize it to the different needs of different programmers. The only way to prevent the library to get out of control is to build components that are generic enough to be applied to many different situation.

Composing components is the step that is completely specific to the reuse-based software development process. Once all the needed components have been found, eventually modified, or developed from scratch, there needs to be a framework where the programmer can specify how to compose these components together to build the targeted application.

ESL vs Reuse

The ESL concept of Reuse is based on the following principles: ESL is targeted toward domain specialists who do not have a sufficient knowledge of Ada programming language to develop code in their domain. The tool would allow them to graphically develop an application from the available pieces of code stored in a software component library. We should point out here, that the ESL system does not address the issue of developing the elementary components that are populating the library. It takes as a first assumption that these components exist, that they are medium to gross grain components wrtten in Ada, and that they were input in the knowledge base with the proper amount of information to allow their retrieval and their correct use. Based on these assumptions, ESL contains the different mechanisms that allows an application developer to build the program he needs from the stored components. Let us now focus on the different parts of ESL:

• The first part of ESL deals with the storage of the components. The sytem is built on a knowledge base writen in ART-IM. This knowledge base contains the important information about the components such as what it does, what the inputs and outputs are, if the component is composed of other components or if it is an elementary one.

• The second part of ESL addresses the issue of retrieving a component. ESL has a Case Base Reasoning (CBR) engine that allows to query the library for components having some similarities with the needed component. The system will present a list of components belonging to the same class, ordered according to the number of identical attributes values. The application developer can refine his query by analysing the closest component, changing the unfit attributes and then resubmitting the query with the added information.

• The third part of ESL focus on assembling the retrieved components in order to build an application. A graphical editor allows the application developer to graphically link the desired components.

• The fourth part of ESL is the code generator. From the graphical representation of the flow of inputs and triggers through the different components, ESL generates an Ada main program that contains the calls to the different routines chosen by the user.

1.1 Description of the ESL Reusable method

The Engineering Script Language (ESL) is a language designed to allow non programming users to write High Order Language (HOL) programs by drawing directed graphs to represent the program and having the system generate the corresponding program in HOL. For the implementation of ESL proposed, the HOL code to be generated will be Ada.

The building blocks for directed graphs are nodes and connectors. Nodes are visually represented as labeled icons (e.g., rectangles or circles) and have input and output ports which are used to receive produce data. On a graph, an output port from one node may be connected to an input node on another node via a connector. Visually, all connectors passing data between two nodes are represented as a single arrow connecting the icons representing the nodes. In addition, a graph itself can have input ports and output ports which are connected to ports or nodes on the graph. Visually, the set of all graph input ports is represented by a single icon on the left of the editor window. Each arrow from this icon to a node on the graph represents a group of connectors. Similarly, the set of all graph output ports is represented visually as a single icon on the right of the editor window.

Each node on a graph may represent a primitive procedure or function in the HOL (i.e., a primitive subprogram), an ESL control or data-passing mechanism, or another graph. When a node is a primitive subprogram node, the node's ports represent the subprogram's parameters and, if applicable, its return value.

Node Objects

There are several classes of node objects: the subprogram node, (which includes procedure-node, function-node, and subgraph-node objects), the Merge node, the Replicator node, and the control nodes (If, Select, and Iterator).

A subprogram-node object is used to represent a procedure or function coded in the HOL or to represent a graph previously created through the ESL editor. Each subprogram-node object points to a subprogram object. Subprogram objects are objects visible through the ACCESS tools panel and included in the ACCESS taxonomy.

Subprogram objects have corresponding ports. Ports of a procedure or a function object represent parameters of the corresponding procedure or function or the return value of the function. Ports of a graph object, called graph ports, are mapped to ports on nodes of the graph by connector objects.

Implementation Objects

An implementation object contains information about how a subprogram object is implemented. The merge, replicator, If, Select and Iterator nodes each have an implicit implementation and do not have an associated implementation object. There are three classes of implementation objects.: Inline, seperately compiled procedure, and package.

Inline implementation objects are appropriate only for graph objects. This type of implementation means that when a subgraph node is part of a larger graph for which code is generated, the code corresponding to the subgraph node is generated online.

Implementation objects whose type is seperately compiled procedure are valid for all subprogram objects. Such an implementation object indicates that the subprogram is implemented as a seperately compiled Ada procedure. For a seperately compiled procedure to be called by an Ada program, the program must be first "with" the procedure; then the procedure may be called.

Package implementation objects are valid for subprograms of procedure or function type. Such an implementation object indicates that the subprogram has been implemented as a visible function in an Ada package. For a procedure or function in a package to be called by an Ada program, the program must first "with" the package; then the procedure may be called using the "package.procedure" notation.

Object Hierarchy

***** FIRST DRAFT *****

The following is the hierarchy of objects in ESL system.

- subprogram
  - primitive subprogram
    - function
    - procedure
  - graph
- node
  - subprogram node
    - primitive subprogram node
    - procedure node
    - function node
  - subgraph node
  - merge node
  - replicator node
  - control node
    - if node
    - select node
    - iterator node
- port
  - graph port
  - procedure port
  - function port
  - node port
- connector group
- connector
- implementation
  - inline implementation
    - seperately complied procedure implementation
  - package implementation
- data type

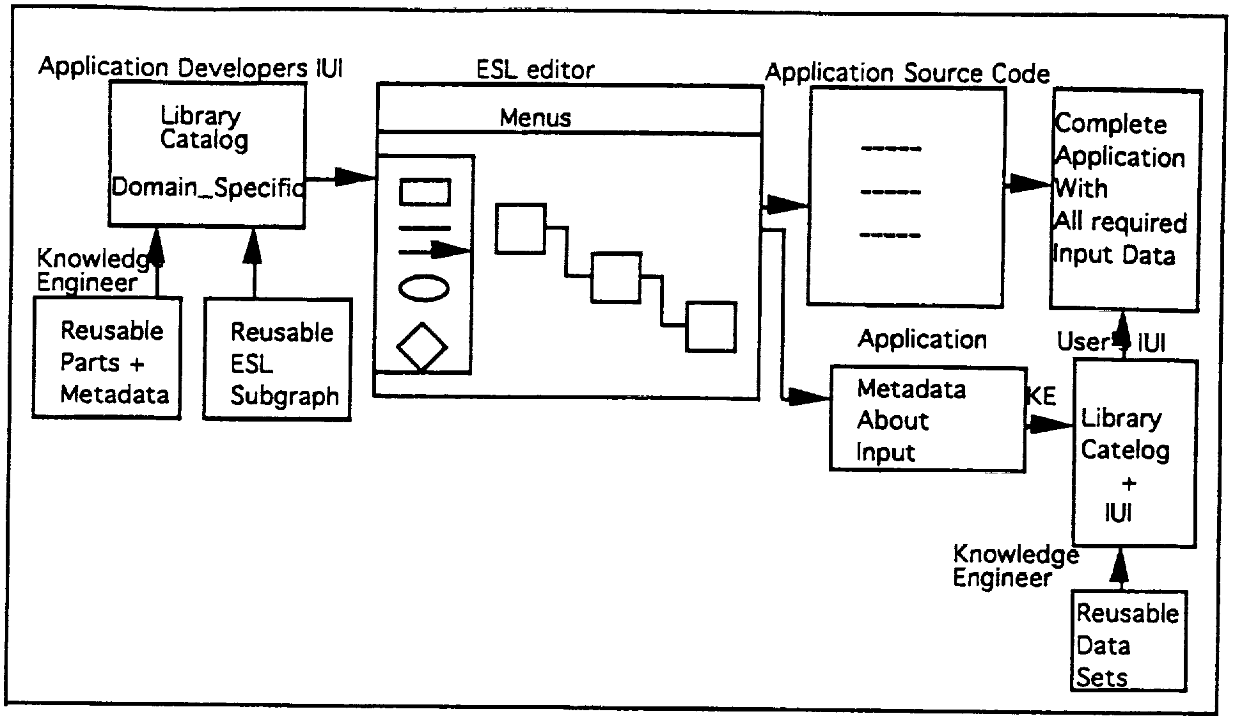


Fig. 1.1.1 Building an Application Program with the help of a Parts Composition System

Figure 1.1.1 shows the various steps that would be involved in building a complete application with the help of a Parts Composition System (PCS), as currently envisioned. A library of procedures (or more generically, primitives) containing software parts that are needed by most application programs within the domain of interest is opened and scanned. If this library contains most of the required primitives, then the application developer may select to use it; otherwise, additional libraries may be searched.

Depending on the decisions of the libraries' management organizations, application developers may or may not be allowed to create modified versions of primitives in the libraries. However, the development, organization, and maintenance of these domain-specific libraries is primarily the responsibility of the software development engineers and not the job of the application developers, who may well be aerospace engineers with minimal programming experience. The software development engineers receive part specifications from the application developers and provide implementations to populate required libraries. If well managed, this seperation of roles helps to limit the amount of domain expertise that the software engineer must have and also the amount of programming experience that the application developer must have.

The construction of primitives can be done using the Computer-Aided Software Engineering (CASE) tools. However, a useful, well-maintained library of reusable parts consists of more than a disorganized jumble of parts. A librarian and library tools are clearly required. A librarian must build and maintain a PCS knowledge base using tools that extract the necessary metadata from each primitive (such as input, output, purpose, and constraints) and then catalog this information with the knowledge base's schemas. The cataloging process includes the assignment of each primitive to a specific knowledge base class. Careful development of a meaningful class structure is essential to the usefulness of the library's catalog and one of the most challenging tasks of the knowledge engineer. Special displays may also bo required for some classes of primitives in order to make the catalog as user friendly as possible. In short, the knowledge engineer must build an IUI for each domain-specific library of reusable parts. His/her role is to serve as the intermediary between the software development engineers and the application developers.

Once an application developer has selected the most appropriate domain-specific library of parts, he/she invokes the ESL editor. As already explained, the ESL editor allows the application developer to create, modify, store and retrieve graphs that represent applications. The graphs show the structure of an application and what data controls and constraints flow between the components (fig.1.1.2) The components are depicted by boxes called nodes, and the data controls, and constraints are shown as arrows linking the nodes. Other structures, also called nodes, allow for merging and replicating links and for including looping and branching logic. Each component (box) is either a primitive or a subgraph, which makes possible hierarchical decomposition. (fig.1.1.2)

With ESL editor, an application developer uses a mouse and pointer to select menu and palette commands and to select nodes and links on the screen. In this way, graphs are constructed, modified, and stored for possible reuse.

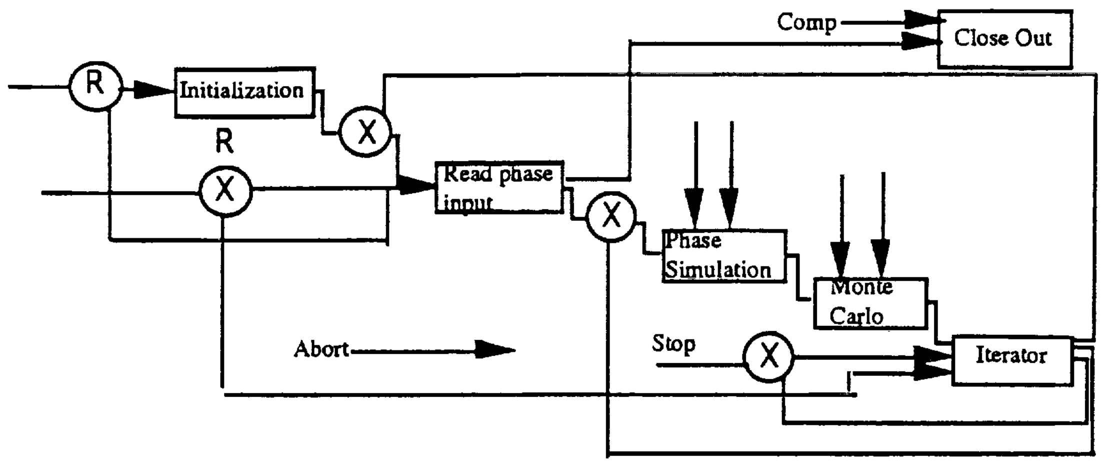


Fig.1.1.2 A typical ESL Graph

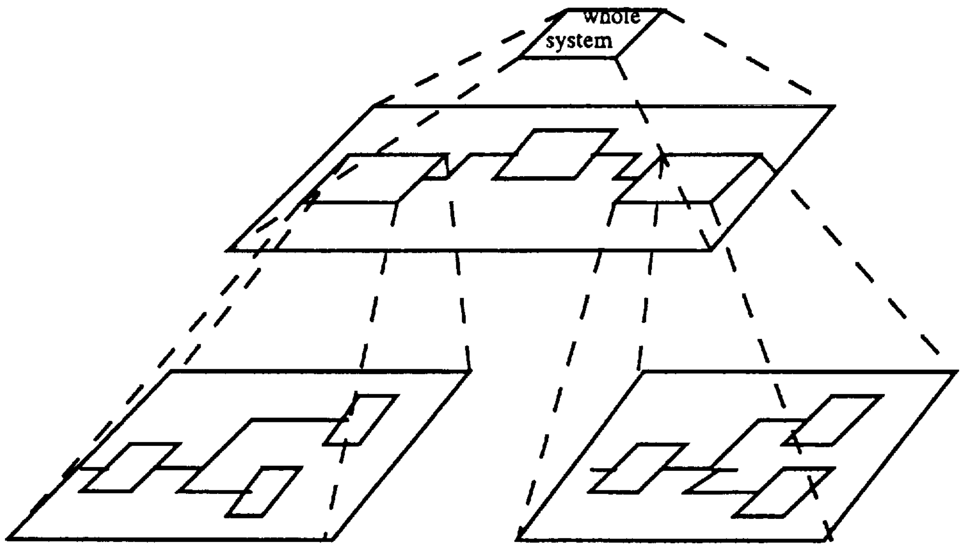


Fig. 1.1.3 Hierarchical Decomposition of ESL graphs

Once the graphs representing an application are completed, the application developer will invoke menu commands to validate the graph system and to generate the required code in some high order language, such as Ada. The generated code, in the form of a main program and subprograms, will then be ready to be compiled and linked with the object code of the primitives from the domain specific library(ies). Alternatively, source code templates (such as Ada generics or even main programs with certain parameters that must be initialized before compilation) might be generated, if required.

ESL graphs will be stored in a knowledge base, where they will be represented, using a schema system, as objects with attributes. The ability to store and retrieve ESL graphs implies a need for well-organized, domain-specific libraries of graphs with good library catalogs. Just as in the case of the libraries of primitives, a knowledge engineer will need to create IUI s for the ESL graph libraries.

The internal representation and storage of graphs, the semantic interpretation and validation of the graphs, and the generation of code in high order language are done using knowledge-based technology.

Graph Implementation and Execution

Fig 1.1.4 depicts a typical example graph created using the ESL editor panel. Each box is an instance of an object. In other words each box is merely a procedure call or a function call. The iterator node indicates an iteration at that particular point until a certain condition is satisfied. INNER_LOOP is a sub graph attatched to the main graph. It is a seperately edited graph. The sub graph is shown in fig. 1.1.5.

Prior to executing a complete application, the graphs must be translated to a hign order language (HOL) representation and subsequently compiled. A graph implementation is an HOL representation of a hierarchical ESL data flow graph that can be compiled by a standard HOL compiler for subsequent execution. The translation process generates the graph implementation by mapping the features found in the application's graph schemas to predefined

HOL constructs.

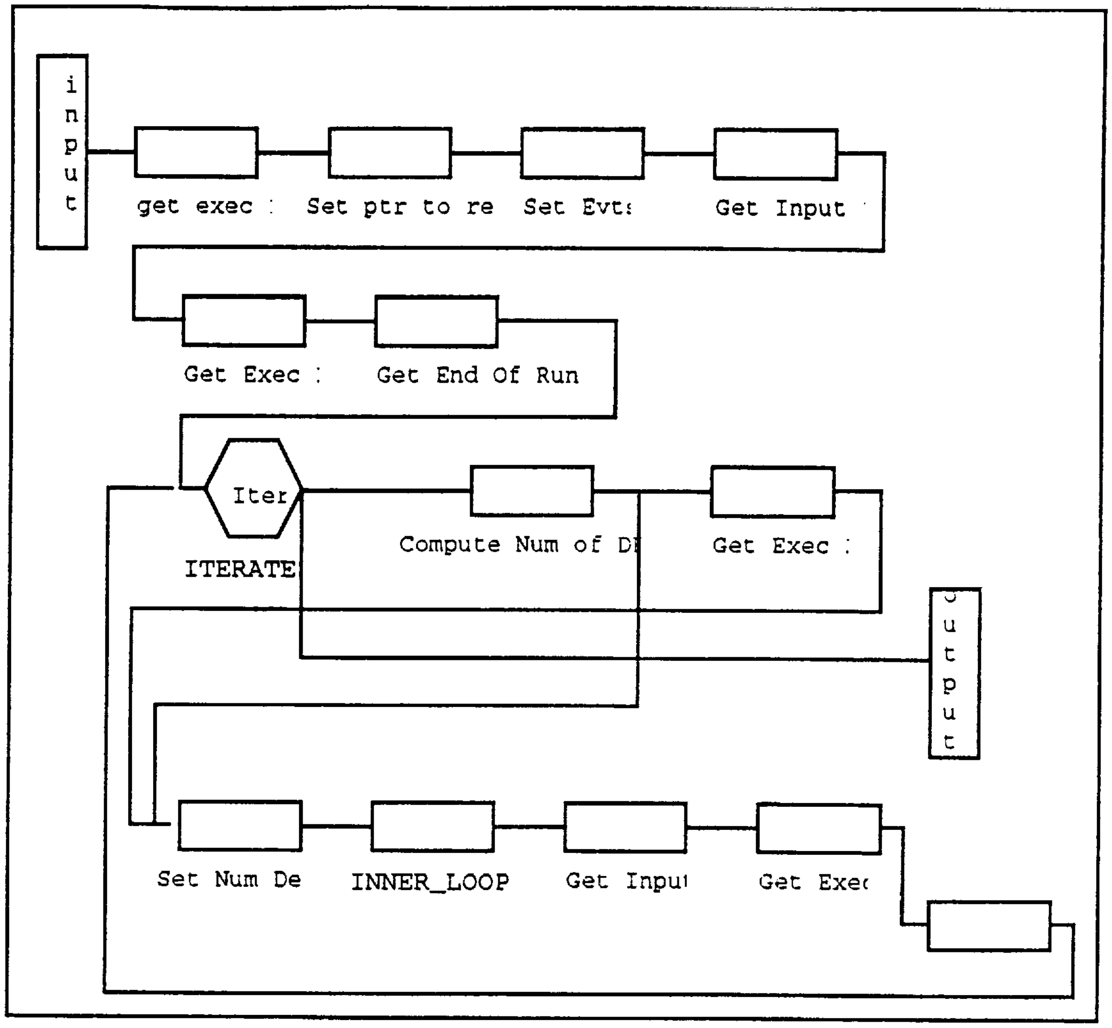


Fig. 1.1.4 An ESL graph example

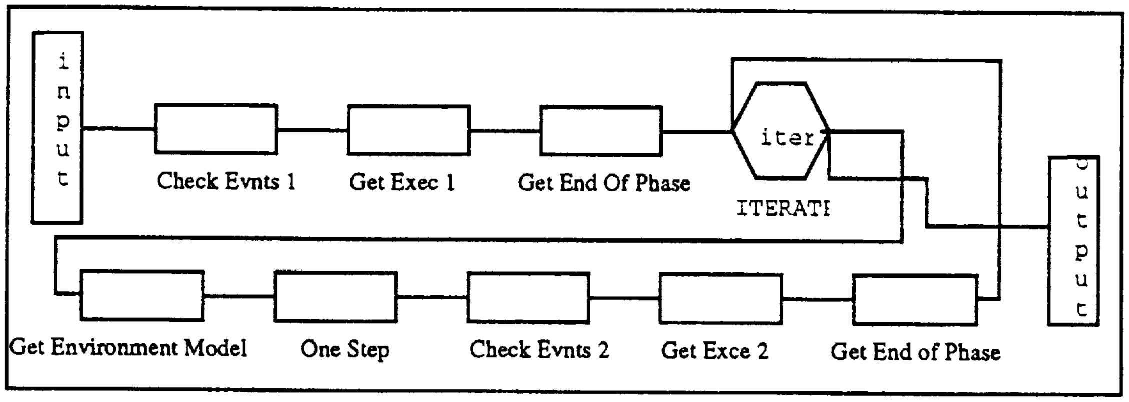


Fig. 1.1.5 ESL sub graph for INNER_LOOP

Generated Code

```
- -
– Ada code for graph six_dof_driver
- -

with ASDS_Exec_Record_Manager;
with six_dof_driver_inner;
wth Environment_model;
with Six_Dof_Instantiations;
With state_types;

procedure six_dof_driver is

        TEST18 : Boolean := TRUE;

        Exec15  : ASDS_Exec_Record_Pointer_type;
        Exec20  : ASDS_Exec_Record_Pointer_type;
        Num_Diff_Eq16 : Positive;
        Exec17 : ASDS_Exec_Record_Pointer_Type;
        Exec19 : ASDS_Exec_Record_Pointer_Type;

begin

        – Code for node Get Exec 1
        Exec15 := Six_DOF_Instantiations.Get_Exec;

        -- Code for node Set ptr to rec
        ASDS_Exec_Record_Manager.set_pointer_to_ASDS_EXEC_record(Exec15);

        -- Code for node Set Evts
        Six_DOF_Instantiations.Sst_Discrete_Events;

        – Code for node Get Input 1
        Six_DOF_Instantiations.Six_DOF_INPUT.Get_Input;

        – Code for node Get Exec 2
        Exec19 := Six_DOF_Instantiations.Get_Exec;

        -- Code for node Get End of Run 1
        Test18 := Six_DOF_Instantiations.Get_End_Of_Run(Exec19);

        – Code for ITERATE
        while (TEST18) loop

                – code for node Compute Num of DEs
                Num_Diff_Eq16 := State_Type.Compute_Num_Of_Diff_Ef;

                – Code for node Get Exec 3
                Exec17 := Six_DOF_Inatantiations.Get_Exec;

                – Code for node Set Num DEs
                Six_DOF_Instantiations.Set_Num_Diff_Eq(Exec17, Num_Diff_Eq16);
                -- Code for node inner loop
                Six_dof_driver_inner;

                -- Code for node Get Input
                Six_DOF_Instantiations.six_DOF_Input.Get_Input;

                -- Code for node Get Exec
                Exec20 := Six_DOF_Instantiations.Get_Exec;

                -- Code for node Get End of Run
                TEST18 := Six_DOF_Instantiations.Get_End_Of_Run(Exec20);
        end loop;
end  six_dof_driver;
```

1.2 Description of the FM tool kit applications.

1.3 Methods used to reengineer FM tool kit code to ESL Reusable Method.

As described in section 1.1, we know that the code generated by a designed graph in the ESL system, would be either a main program or a sub program. Also we have mentioned , that a main program or a sub program can be a single procedure or a function call or a set of procedure or function calls or a set of procedure and function calls. In addition, a main program or a sub program can have loop structures and if-then-else structures. An important point is that, ESL does not support nested loop structures. This is one of the limitations provided in the ESL system. Hence, primarily, we need to realize that, reengineering any application should be done within this limited ESL framework.

Section 1.2 provides a thorough description of the FM tool kit which is in question to reengineer within the ESL framework.

Currently FM tool kit said to have eleven applications. These source code have been developed in Ada. These applications look very similar. For our "reengineering-for-ESL" purposes, four of these applications - namely INTRPLAN, IPCAPTUR, BEST1WAY and POWRSWNG , have been randomly selected. A vital part of the "reengineering-for-ESL" process is to develop a library of procedures (or more generally, PRIMITIVES) containing the reusable software components , so that they can be put together to form a complete application.

Analysis of FM-Tool kit applications

Initially, let us consider the two applications INTRPLAN & IPCAPTUR. The code shown below (Fig. 1.3.1 & Fig. 1.3.2) depicts the main programs of the above two applications.

```
with INTRPLEC ;  use INTRPLEC ;
with INTRPLIO ;  use INTRPLIO ;

procedure INTRPLAN is

begin
RETRIEVE_PREVIOUS_INPUTS_FROM_DISK                                               ;
LET_USER_EDIT_INPUT_DATA                                                         ;
SAVE_EDITED_INPUTS_ON_DISK                                                       ;
SET_UP_CONSTANTS_AND_PLANETARY_EPHEMERIDES                                       ;
DISPLAY_DATA_SHELL        ( NOMINAL_DEPARTURE_DELTA_V            )               ;
for J in 0..10 loop
     COMPUTE_POSITION_AND_VELOCITY_OF_TARGET_PLANET    (     J )                 ;
     for I in 0..16 loop
          COMPUTE_POSITION_AND_VELOCITY_OF_HOME_PLANET ( I     )                 ;
          COMPUTE_TRAJECTORY_DATA                      ( I, J )                  ;
          DISPLAY_VALUE  ( NOMINAL_DEPARTURE_DELTA_V   , I, J )                  ;
          CHECK_FOR_INTERRUPT_FROM_KEYBOARD                                      ;
          end loop                                                               ;
     end loop                                                                    ;
DISPLAY_TRAJECTORY_DATA_OF_INTEREST_TO_USER                                      ;
end                                                                              ;
```

Fig 1.3.1 - Main Program for INTRPLAN

```
with IPCAPTEC ;  use IPCAPTEC ;
with IPCAPTIO ;  use IPCAPTIO ;

procedure IPCAPTUR is

begin
RETRIEVE_PREVIOUS_INPUTS_FROM_DISK                                               ;
LET_USER_EDIT_INPUT_DATA                                                         ;
SAVE_EDITED_INPUTS_ON_DISK                                                       ;
SET_UP_CONSTANTS_AND_PLANETARY_EPHEMERIDES                                       ;
DISPLAY_DATA_SHELL        ( NOMINAL_DEPARTURE_DELTA_V            )               ;
for J in 0..10 loop
     COMPUTE_POSITION_AND_VELOCITY_OF_TARGET_PLANET    (     J )                 ;
     for I in 0..16 loop
          COMPUTE_POSITION_AND_VELOCITY_OF_HOME_PLANET ( I     )                 ;
          COMPUTE_TRAJECTORY_DATA                    ( I, J )             ;
          DISPLAY_VALUE  ( NOMINAL_DEPARTURE_DELTA_V  , I, J )             ;
          CHECK_FOR_INTERRUPT_FROM_KEYBOARD                               ;
          end loop                                                        ;
     end loop                                                             ;
DISPLAY_TRAJECTORY_DATA_OF_INTEREST_TO_USER                               ;
end                                                                       ;
```

Fig 1.3.2 - Main program for IPCAPTUR

The two main programs look exactly the same, except for the different dependent library units. (i.e intrplec & intrplio for INTRPLAN and ipcaptec & ipcaptio for IPCAPTUR). In ESL terms these two are non primitives , because they do not have any computational instructions but a set of module calls. Therefore a major modification is not required except for the elimination of the FOR loops. (In ESL, nested looping structures are not allowed.).

A simple solution to this is to incorporate the inner FOR loop in a separate module and isolate it. Then the two main program structures will look as follows.

```
with IPCAPTEC ;  use IPCAPTEC ;
with IPCAPTIO ;  use IPCAPTIO ;

procedure IPCAPTUR is

begin
RETRIEVE_PREVIOUS_INPUTS_FROM_DISK                                        ;
LET_USER_EDIT_INPUT_DATA                                                  ;
SAVE_EDITED_INPUTS_ON_DISK                                                ;
SET_UP_CONSTANTS_AND_PLANETARY_EPHEMERIDES                                ;
DISPLAY_DATA_SHELL                  ( TOTAL_DELTA_V        )              ;
for J in 0..10 loop
     COMPUTE_POSITION_AND_VELOCITY_OF_TARGET_PLANET    (    J )           ;
     INNER_LOOP;
end loop                                                             ;
DISPLAY_TRAJECTORY_DATA_OF_INTEREST_TO_USER                               ;
end                                                                       ;
```

FIG. 1.3.3a

```
with INTRPLEC ;  use INTRPLEC ;
with INTRPLIO ;  use INTRPLIO ;
```

```
procedure INTRPLAN is

begin
RETRIEVE_PREVIOUS_INPUTS_FROM_DISK                                         ;
LET_USER_EDIT_INPUT_DATA                                                   ;
SAVE_EDITED_INPUTS_ON_DISK                                                 ;
SET_UP_CONSTANTS_AND_PLANETARY_EPHEMERIDES                                 ;
DISPLAY_DATA_SHELL        ( NOMINAL_DEPARTURE_DELTA_V         )            ;
for J in 0..10 loop
     COMPUTE_POSITION_AND_VELOCITY_OF_TARGET_PLANET     (    J )           ;
     INNER_LOOP;
end loop                                                               ;
DISPLAY_TRAJECTORY_DATA_OF_INTEREST_TO_USER                                ;
end                                                                        ;
```

FIG. 1.3.3b

```
procedure INNER_LOOP is
begin
      for I in 0..16 loop
          COMPUTE_POSITION_AND_VELOCITY_OF_HOME_PLANET ( I    )            ;
          COMPUTE_TRAJECTORY_DATA                      ( I, J )            ;
          DISPLAY_VALUE               ( TOTAL_DELTA_V , I, J )             ;
          CHECK_FOR_INTERRUPT_FROM_KEYBOARD                                ;
      end loop                                                         ;
end INNER_LOOP;
```

FIG. 1.3.3c

The module INNER_LOOP is the newly created module in order to incorporate the inner FOR loop in the original main program of both INTRPLAN and IPCAPTUR. As a matter of fact , this new procedure automatically have become a reusable component. Further, the new main program is just a set of module calls with one single loop structure. But the FOR loop must be changed to a WHILE loop as to fulfil ESL requirements. We have discussed this later in this section.

The above modification is inadequate. Of interest to us is whether, the modified main programs INTRPLAN and IPCAPTUR can be represented in an ESL graph. A straight answer is NO. Still we need to change the outer FOR loop structure. We can think of replacing the outer FOR loop structure with a WHILE loop structure as ESL supports WHILE loops. In order to do this, the value of J must be incremented inside the WHILE loop. This can be implemented with a simple computational statement like J := J + 1;

```
with IPCAPTEC ;  use IPCAPTEC ;
with IPCAPTIO ;  use IPCAPTIO ;

procedure IPCAPTUR is
```

```
LOOP_END : boolean := FALSE;
J : integer := 1;
begin
RETRIEVE_PREVIOUS_INPUTS_FROM_DISK                                           ;
LET_USER_EDIT_INPUT_DATA                                                     ;
SAVE_EDITED_INPUTS_ON_DISK                                                   ;
SET_UP_CONSTANTS_AND_PLANETARY_EPHEMERIDES                                   ;
DISPLAY_DATA_SHELL                        ( TOTAL_DELTA_V        )           ;
while LOOP_END = FALSE loop
     COMPUTE_POSITION_AND_VELOCITY_OF_TARGET_PLANET    (    J )              ;
     INNER_LOOP;
     J := J + 1;
     if J > 10 then
        LOOP_END := TRUE;
     end if;
end loop                                                                ;
DISPLAY_TRAJECTORY_DATA_OF_INTEREST_TO_USER                                  ;
end
```

FIG. 1.3.4

The above is the modified main program code for IPCAPTUR. (Considering the main program of IPCAPTUR is good enough for the time being). Changing the inner FOR loop into a WHILE loop caused us to incorporate few other additional statements (FIG. 1.3.5) within the WHILE loop.

```
J := J + 1;
if J > 10 then
   LOOP_END := TRUE;
end if;
```

FIG. 1.3.5
Added Computational Statements inside the WHILE loop

The question is whether the modified main program shown in figure 1.3.4 is good enough to construct an ESL graph. Again, a straight answer is NO. The simple reason is that, there cannot be any computational statements within a piece of code except for a set of module calls , to construct the corresponding ESL representation. Hence a solution is to further decompose the main-program (of INTRPLAN & IPCAPTUR); meaning, removing the outer FOR loop and incorporate it in a separate module, and call that module from the main program. The figure 1.3.7 shows the final picture of the main program for INTRPLAN and IPCAPTUR.

```
with IPCAPTEC ;  use IPCAPTEC ;
with IPCAPTIO ;  use IPCAPTIO ;
```

```
procedure IPCAPTUR is

begin
RETRIEVE_PREVIOUS_INPUTS_FROM_DISK                                             ;
LET_USER_EDIT_INPUT_DATA                                                       ;
SAVE_EDITED_INPUTS_ON_DISK                                                     ;
SET_UP_CONSTANTS_AND_PLANETARY_EPHEMERIDES                                     ;
DISPLAY_DATA_SHELL                    ( TOTAL_DELTA_V         )                ;
MAIN_LOOP;
DISPLAY_TRAJECTORY_DATA_OF_INTEREST_TO_USER                                    ;
end                                                                            ;
```

FIG. 1.3.6a

```
with INTRPLEC ;  use INTRPLEC ;
with INTRPLIO ;  use INTRPLIO ;

procedure INTRPLAN is

begin
RETRIEVE_PREVIOUS_INPUTS_FROM_DISK                                             ;
LET_USER_EDIT_INPUT_DATA                                                       ;
SAVE_EDITED_INPUTS_ON_DISK                                                     ;
SET_UP_CONSTANTS_AND_PLANETARY_EPHEMERIDES                                     ;
DISPLAY_DATA_SHELL        ( NOMINAL_DEPARTURE_DELTA_V          )               ;
MAIN_LOOP;
DISPLAY_TRAJECTORY_DATA_OF_INTEREST_TO_USER                                    ;
end                                                                            ;
```

FIG. 1.3.6b

where MAIN_LOOP is the newly created procedure to incorporate the outer loop in the main program(s) (FIG 1.3.7).

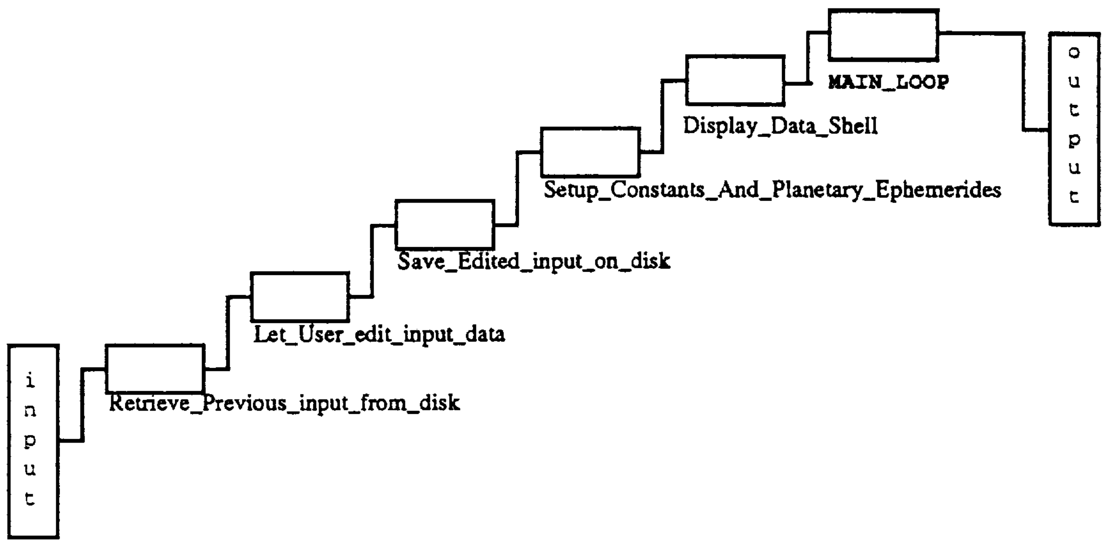
```
procedure MAIN_LOOP is


begin
  for J in 1..10 loop
       COMPUTE_POSITION_AND_VELOCITY_OF_TARGET_PLANET (    J )               ;
       INNER_LOOP;
  end loop;
                                                              ;
end MAIN_LOOP;
```

FIG. 1.3.7

The final main program(s) is purely a set of module calls and within ESL requirements. The ESL graphical representation to create the main program structure is shown in FIG. 1.3.8.

FIG. 1.3.8

ESL Graphical Representation of The Main Program for INTRPLAN or IPCAPTUR


input
Retrieve_Previous_input_from_disk
Let_User_edit_input_data
Save_Edited_input_on_disk
Setup_Constants_And_Planetary_Ephemerides
Display_Data_Shell
MAIN_LOOP
output

The decomposition of the main program(s) caused create two new procedures INNER_LOOP and MAIN_LOOP. Obviously, these two procedures have the format of a ESL sub program where, only module calls are allowed. But first we need to modify the module MAIN_LOOP. Introduction of a WHILE loop and to have a separate procedure for the portion shown in fig.1.3.5 would be the main modifications. Fig. 1.3.9 illustrates the MAIN_LOOP after the modifications.

```
procedure MAIN_LOOP is

LOOP_END : boolean := false;
CONST : integer CONSTANT := 10      ;

begin
    while LOOP_END = false loop
       COMPUTE_POSITION_AND_VELOCITY_OF_TARGET_PLANET (    J )              ;
       INNER_LOOP;
       SET_CONTROL(J, LOOP_END, CONST);
    end loop;
                                                                          ;
end MAIN_LOOP;
```

FIG. 1.3.9

where SET_CONTROL is another new procedure, created to incorporate the small portion of code shown in fig. 1.3.5. This is shown in FIG. 1.3.10

```
procedure SET_CONTROL( J_IN  : integer; DONE : boolean; CONST : integer) is

begin
         J_IN := J_IN + 1;
          if J_IN > CONST then
             DONE := TRUE;
           end if;
end SET_CONTROL;
```

FIG. 1.3.10

The benefit of making this modifications is that the software component SET_CONTROL is now converted to a reusable module. Hence this same module can be called by the procedure INNER_LOOP, by making similar modifications as done for the module MAIN_LOOP. Fig. 1.3.11 shows the modified procedure INNER_LOOP.

```
procedure INNER_LOOP is

LOOP_END : boolean := FALSE;
CONST : integer CONSTANT := 16;
begin
   while LOOP_END = FALSE loop
          COMPUTE_POSITION_AND_VELOCITY_OF_HOME_PLANET ( I    )        ;
          COMPUTE_TRAJECTORY_DATA                      ( I, J )        ;
          DISPLAY_VALUE              ( TOTAL_DELTA_V , I, J )        ;
          CHECK_FOR_INTERRUPT_FROM_KEYBOARD                            ;
          SET_CONTROL(J, LOOP_END, CONST);
    end loop;
end INNER_LOOP;
```

FIG 1.3.11

It is now very clear that the two procedures INNER_LOOP and the MAIN_LOOP are converted into ESL subprograms. Figures 1.3.12 and 1.3.13 illustrate the ESL graphical representation of the two subprograms.

FIG. 1.3.12
The ESL object graph for subprogram MAIN_LOOP

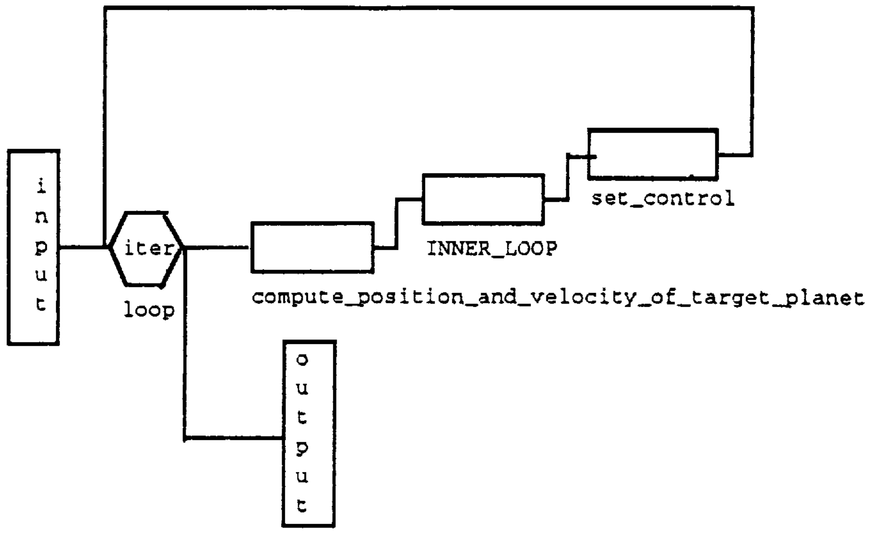
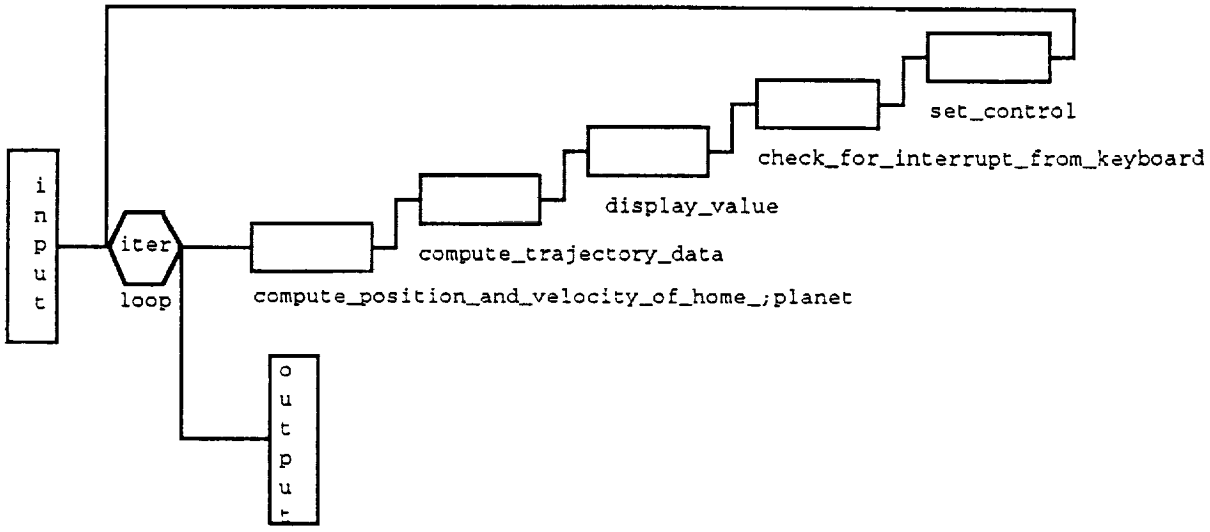


FIG. 1.3.13
The ESL object graph for subprogram INNER_LOOP


input
iter
loop
compute_position_and_velocity_of_home_;planet
compute_trajectory_data
display_value
check_for_interrupt_from_keyboard
set_control
output

The same ESL object graph could be used for BEST1WAY . It is important to make sure that the user set proper constant values when modules being called for individual applications. For example, the contant value passed into the reusable module SET_CONTROL, must be properly set inside procedures MAIN_LOOP and INNER_LOOP. i.e values 10 and 16 respectively for INTRPLAN and IPCAPTUR. Similarly, for BEST1WAY.

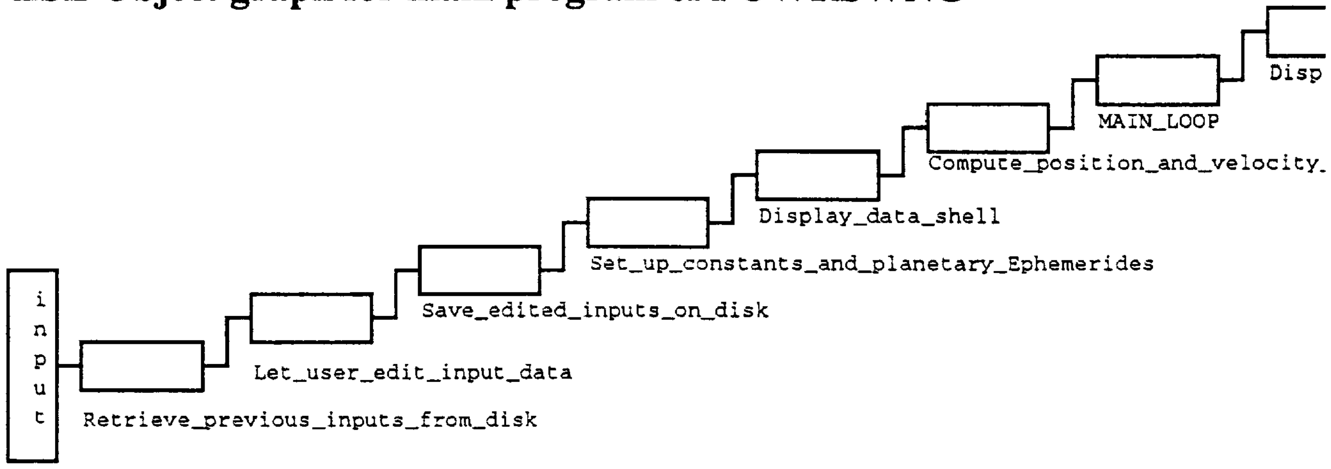
Comparatively, main program for POWERSWNG looks slightly different to the main programs of the other three applications. But of course, many of the modules already modified for reusable purposes can be used in designing ESL object graph for POWERSWNG. For POWRSWNG, the following procedure calls, must be added.

COMPUTE_POSITION_AND_VELOCITY_OF_SWINGBY_PLANET
COMPUTE_TRAJECTORY_FOR_FIRST_HELIOCENTRIC_LEG
DISPLAY_VALUE1
DISPLAY_VALUE2
COMPUTE_TRAJECTORY_FOR_SECOND_HELIOCENTRIC_LEG

The following is the ESL graphical representation for POWRSWNG.

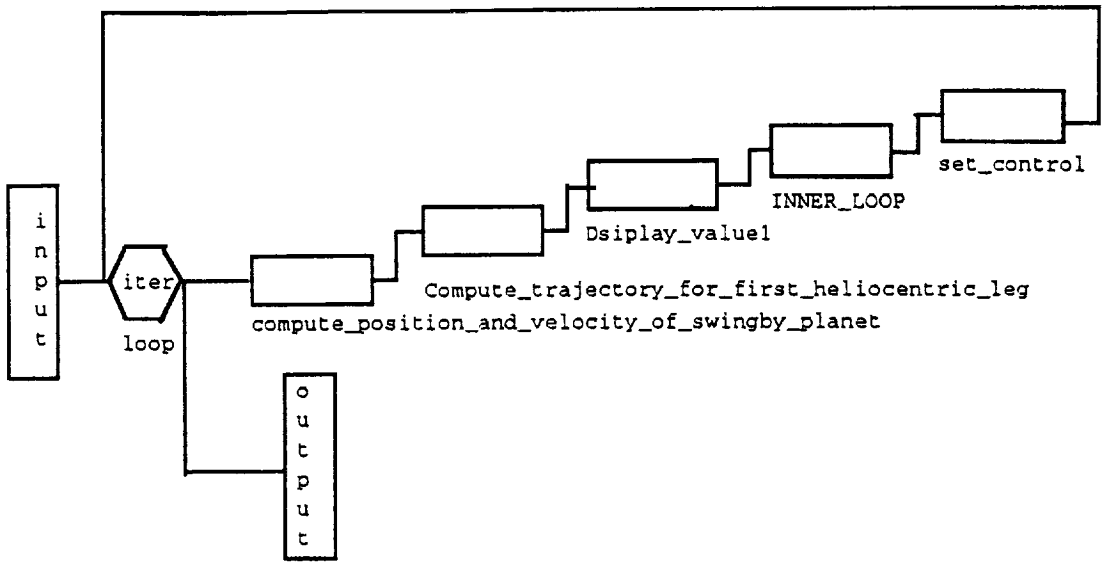
FIG. 1.3.14

ESL Object graph for main program of POWRSWNG


input
Retrieve_previous_inputs_from_disk
Let_user_edit_input_data
Save_edited_inputs_on_disk
Set_up_constants_and_planetary_Ephemerides
Display_data_shell
Compute_position_and_velocity_
MAIN_LOOP
Disp

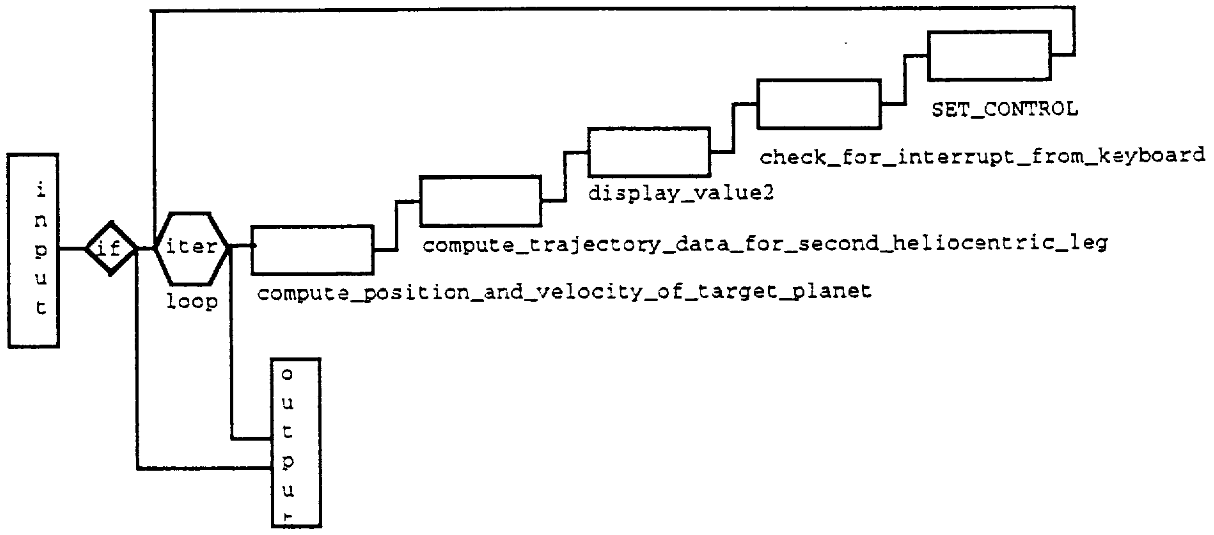
*** FIRST DRAFT ***

FIG. 1.2.15
The ESL object graph for subprogram MAIN_LOOP



input
iter
loop
compute_position_and_velocity_of_swingby_planet
Compute_trajectory_for_first_heliocentric_leg
Dsiplay_value1
INNER_LOOP
set_control
output

FIG. 1.2.16
The ESL object graph for subprogram INNER_LOOP of POWRSWNG



input
if
iter
loop
compute_position_and_velocity_of_target_planet
compute_trajectory_data_for_second_heliocentric_leg
display_value2
check_for_interrupt_from_keyboard
SET_CONTROL
output

1.3.2 Modifications and Decomposition of Primitives.

In ESL terms, Primitives are the modules that cannot be further decomposed or modules that are not worth decomposing. For example the module RETRIVE_PREVIOUS_INPUTS_FROM_DISK is a repeated module in all four applications in question. Though the module in POWRSWNG is slightly different to the module in other three applications, all four modules serve the same purpose. Further decomposition is out of question. Hence, best option is to have a single module that serves all four applications, making that a reusable component. Of course, to build a common reusable module, modifications are need to be carried out.

Let us look into the modifications that have been done in order to make this module a reusable component. Originally, not a single parameter was passed into the procedure. As a major modification, two new parameters have been introduced namely FILE_NAME of type **string** and NAME_IN of type **APPLICATION_TYPE**. APPLICATION_TYPE is a user defined type and initially has the enumerated type values INTRPLAN, IPCAPTURE, BEST1WAY, and POWRSWNG. NAME_IN passes in the appropriate value based on the application. FILE_NAME is the data_file name relevant to each application. In other words the corresponding data_file name for INTRPLAN is intrplan.get. Similarly others. Inside the module, CASE and IF_THEN_ELSE structures have been introduced to serve different application types. (See Appendix I)

Modifications have been made to the following procedures in a similar manner.

LET_USER_EDIT_INPUT_DATA
SAVE_EDITED_INPUT_ON_DISK
KILL_OUTDATED_INPUT_FILE
DISPLAY_LINE_LEADERS
DISPLAY_FOOTER_LINES

In each one of the above modules, a new input parameter of APPLICATION_TYPE is introduced. This parameter passes the name of the application that uses this module into the module. This helps to serve the needs of each application program. For instance, POWRSWNG performs a slightly different task in many of the above modules. Passing in the name of the application helps direct the execution to the specific area within the module where those different tasks are carried out. (See appendix I)

1.3.3. Packages COMMON_MODULES, DATA_TYPES, DATA_TYPES_SPEC

The packages COMMON_MODULES, DATA_TYPES, DATA_TYPES_SPEC COMMON_MODULES are the three new packages introduced into the system. The services provided by these packages are described below.

Package COMMON_MODULES.

This is a newly created package build to include all the common reusable procedures and functions. Also this package includes newly created reusable modules as a result of decomposition. For instance, the modules described in section 1.3.1 namely MAIN_LOOP, INNER_LOOP and SET_CONTROL, are residing in package COMMON_MODULES. Of course there are many more modules residing in this package, which we will be discussing later in this report.

Package DATA_TYPES.

This is also a newly created package to include all the type declarations and variable declarations, which are also repeated in all four applications. However this package includes only the data types and type declarations that are found in package bodies of all four application programs.

Package DATA_TYPES_SPEC.

This package is similar to the package DATA_TYPES. This package is created to include all the data types defined in the specifications of application programs.

It is important to make a note that packages DATA_TYPES and DATA_TYPES_SPEC are now directly reusable as all the application programs use these packages.

1.3.4 Further Modifications.

After a thorough analysis of the modules

1. COMPUTE_POSITION_AND_VELOCITY_OF_HOME_PLANET,
2. COMPUTE_POSITION_AND_VELOCITY_OF_TARGET_PLANET,
3. COMPUTE_POSITION_AND_VELOCITY_OF_SWINGBY_PLANET,

it was found that these modules are very similar and perform the same task. Therefore, it is obvious that, from these three modules a single reusable module can be built.

```
procedure COMPUTE_POSITION_AND_VELOCITY_OF_HOME_PLANET ( I : integer ) is

     DT_SECS : FLOTE ;

    begin
    JDATE(HOME) :=  NOM_JDATE(HOME) + LONG_FLOTE(I-8) * INTERVAL(HOME)       ;
    DT_SECS     :=  86400.0 * FLOTE( JDATE(HOME) - PER_JDATE(HOME) )        ;
    PROPAGATE_POSITION_AND_VELOCITY_THRU_TIME (
       PER_HELIPOS(HOME) , PER_HELIVEL(HOME) , DT_SECS , GM_SUNp(HOME) ,
         HELIPOS(HOME) ,    HELIVEL(HOME)                        ) ;
   end                                                ;
```

FIG. 1.3.17

```
procedure COMPUTE_POSITION_AND_VELOCITY_OF_TARGET_PLANET ( J : integer ) is

     DT_SECS : FLOTE ;

    begin
    JDATE(TARG) :=  NOM_JDATE(TARG) + LONG_FLOTE(J-5) * INTERVAL(TARG)       ;
    DT_SECS     :=  86400.0 * FLOTE( JDATE(TARG) - PER_JDATE(TARG) )        ;
    PROPAGATE_POSITION_AND_VELOCITY_THRU_TIME (
       PER_HELIPOS(TARG) , PER_HELIVEL(TARG) , DT_SECS , GM_SUNp(TARG) ,
         HELIPOS(TARG) ,    HELIVEL(TARG)                        ) ;
   end                                                ;
```

FIG. 1.3.18

```
procedure COMPUTE_POSITION_AND_VELOCITY_OF_SWINGBY_PLANET ( J : integer ) is

    DT_SECS : FLOTE ;

  begin
  JDATE(SWBY) :=  NOM_JDATE(SWBY) + LONG_FLOTE(J-5) * INTERVAL(SWBY)      ;
  DT_SECS     :=  86400.0 * FLOTE( JDATE(SWBY) - PER_JDATE(SWBY) )       ;
 PROPAGATE_POSITION_AND_VELOCITY_THRU_TIME (
    PER_HELIPOS(SWBY) , PER_HELIVEL(SWBY) , DT_SECS , GM_SUNp(SWBY) ,
       HELIPOS(SWBY) ,    HELIVEL(SWBY)                   ) ;
  end                                                ;
```

FIG. 1.3.19

Shown above are the three procedures found in all four applications. As we have said earlier, simply these modules do the same task except for a few minor differences. The module shown below is a procedure built in order to perform all three tasks, and is reusable.

```
procedure COMPUTE_POSITION_AND_VELOCITY_OF_PLANET ( I : integer;
                                                    PLANET : PLANET_TYPE;
                                                    NAME : APPLICATION_TYPE ) is
 DT_SECS : FLOTE ;
 TEMP : TRAG_NODE      ;
 COUNTER : integer;

 begin
         case PLANET is
              when TARGET | target => TEMP := TRAG;
                                      if NAME = POWRSWNG then
                                        COUNTER := I - 6;
                                      else
                                        COUNTER := I - 5;
                                      end if;
              when HOME | home     => TEMP := HOME;
                                        COUNTER := I - 8;
              when SWNGBY | swngby => TEMP := SWBY;
                                        COUNTER := I - 5;
              when  others         => null;
         end case;
     if NAME = POWRSWNG AND DESTINATION = SWNGBY then
        JDATE(TEMP) := NOM_JDATE(TEMP);
     else
        JDATE(TEMP) :=  NOM_JDATE(TEMP) + LONG_FLOTE(COUNTER) * INTERVAL(TEMP)       ;
     end if;
     DT_SECS     :=  86400.0 * FLOTE( JDATE(TEMP) - PER_JDATE(TEMP) )         ;
     PROPAGATE_POSITION_AND_VELOCITY_THRU_TIME (
          PER_HELIPOS(TEMP) , PER_HELIVEL(TEMP) , DT_SECS , GM_SUNp(TEMP) ,
              HELIPOS(TEMP) ,     HELIVEL(TEMP)                            )   ;
end   COMPUTE_POSITION_AND_VELOCITY_OF_PLANET;
```

FIG. 1.3.20

This new procedure is named COMPUTE_POSITION_AND_VELOCITY _OF_PLANET, and have three new parameters namely I of type integer, DESTINATION of type DESTINATION_TYPE and NAME_IN of type APPLIATION_TYPE. DESTINATION_TYPE is also a user defined type and it defines the destination (HOME, TARGET or SWINGBY). APPLICATION_TYPE is the same type described earlier.

At this point, it is important to make a note that, creating a new module by the name COMPUTE_POSITION_AND_VELOCITY _OF_PLANET will change the corresponding object name in ESL object graph shown in section 1.3.2

FIG. 1.3.21
The ESL object graph for subprogram MAIN_LOOP

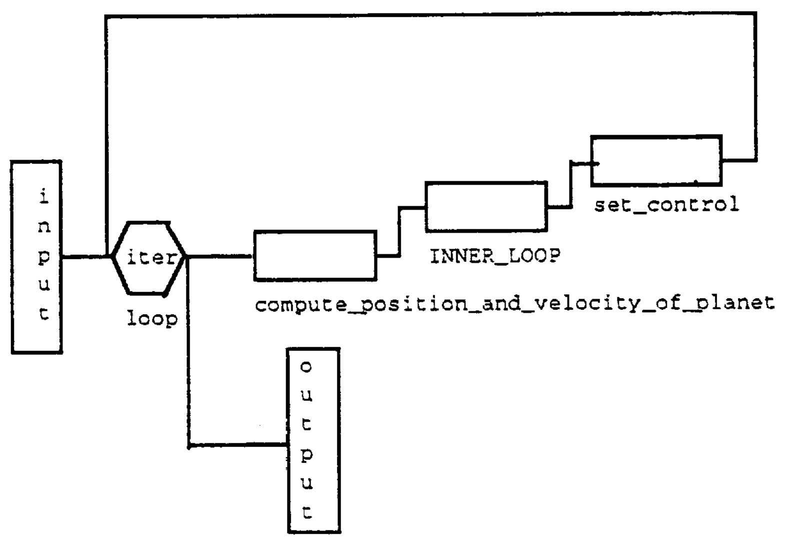
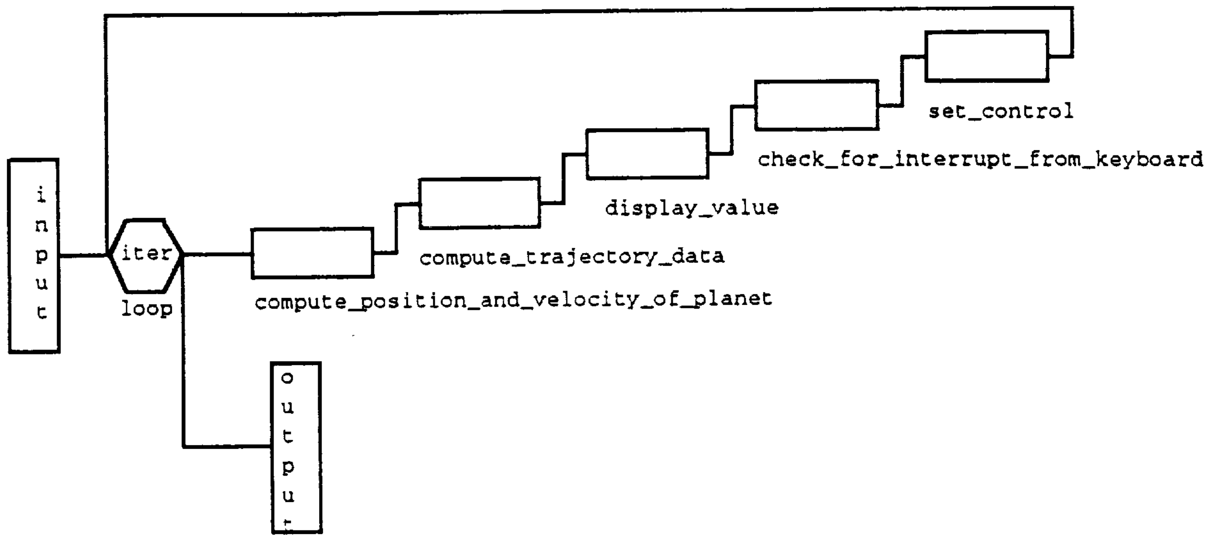


FIG. 1.3.22
The ESL object graph for subprogram INNER_LOOP


input
iter
loop
output
compute_position_and_velocity_of_planet
compute_trajectory_data
display_value
check_for_interrupt_from_keyboard
set_control

Similarly the object names
compute_position_and_velocity_of_home_planet
compute_position_and_velocity_of_target_planet
compute_position_and_velocity_of_swingby_planet

in figures 1.3.15, 1.3.16 and 1.3.18 for POWRSWNG will change accordingly.

1.3.5 Modification of procedure COMPUTE_TRAJECTORY_DATA

Compute_trajectory_data is a another procedure available in all four applications. A thorough analysis revealed that this procedure is an ideal module to decompose and convert into a ESL sub program. Decomposition had to be done so that the grains (decomposed components) could be reused in other similar modules throughout the applications. One major change made in reengineering this module is to eliminate exception handlers. May be this looks very inappropriate, but elimination of exception handlers was necessary to convert this module into a ESL sub program. We know that in ESL a sub program allows only a set of procedure or function calls . Also we need to realize that all these changes must be done having ESL in mind. At this point we need to think of how to tackle the granularity problem. i.e how big a grain is ?. The reason is that, when decomposing the module, very small grains of size one, two or three lines remains within the module. In ESL terms, we cannot leave them within a module. We are forced to eliminate them and reside them in seperate modules.

Let us take a look at how decomposition was done. FIG. 1.3.23 shows decomposed grains by drawing lines in between. Each grain is residing in a procedure with a appropriate procedure name.

```
procedure COMPUTE_TRAJECTORY_DATA ( I, J : integer ) is


          TOO_FAST     : exception ;
          TOO_HOT      : exception ;

          SINFAC       : FLOTE  ;
          TEST_VEC     : VECTOR ;
          TF_DAYS      : FLOTE  ;


     begin
     ----------------------------------------EXCEPTION_HANDLER_10001------------
     TF_DAYS :=  FLOTE( JDATE(TARG) - JDATE(HOME) )                            ;
     if abs( TF_DAYS ) <= 20.0 then
          raise TOO_FAST                                                       ;
          end if                                                               ;
     ----------------------------------------CALCULATIONS-----------------------
     if TF_DAYS > 0.0
          then DEP :=  HOME                                                    ;
          else DEP :=  TARG                                                    ;
          end if                                                               ;
     if DEP = HOME
          then ARR :=  TARG                                                    ;
          else ARR :=  HOME                                                    ;
          end if                                                               ;
     TF_SECS :=  86400.0 * abs( TF_DAYS )                                      ;
     ANGMO_PREF :=  HELIPOS(DEP) * HELIVEL(DEP)                                ;
     TEST_VEC   :=  HELIPOS(DEP) * HELIPOS(ARR)      ; -- * gives cross product
     if TEST_VEC & ANGMO_PREF < 0.0                    -- & gives dot   product
          then SINFAC := -ABS( TEST_VEC )                                      ;
          else SINFAC := +ABS( TEST_VEC )                                      ;
          end if                                                               ;
     XFR_ANG := FULL_REVS*TWOPI + ATAN1( SINFAC, HELIPOS(DEP)&HELIPOS(ARR) )   ;
     DVALUE( HELIOCENTRIC_TRANSFER_ANGLE )(I,J) :=  DATA_MATRIX_INTEGER(
                                                DEGPERRAD * XFR_ANG )          ;
     DVALUE( FLIGHT_TIME )(I,J) :=  DATA_MATRIX_INTEGER( TF_DAYS )             ;
     ---------------------------------------------------------------------------
     FIND_BEST_TRANSFER_TRAJECTORY                                             ;
     ----------------------------------------CALL_FOR_EXCEPTION_HANDLER_10003_10004
     if ( FULL_REVS > 0 ) and ( SMA_SIZE /= BEST_SIZE ) then
          SOLVE_LAMBERT_PROBLEM ( HELIPOS(DEP), TF_SECS, HELIPOS(ARR),
                  ANGMO_PREF, XFR_HELIVEL(DEP),      XFR_HELIVEL(ARR),
                  GM_SUN     ,          FULL_REVS,             BEST_SIZE )     ;
          end if                                                               ;
     ----------------------------------------EXCEPTION_HANDLER_10002------------
     if ARRIVAL_SPEED_PENALTY > 0.0 then
          raise TOO_HOT                                                        ;
          end if                                                               ;
     ---------------------------------------------------------------------------
     COMPUTE_HELIOCENTRIC_TRAJECTORY_DATA   ( I, J )                          ;
     COMPUTE_PLANETOCENTRIC_DEPARTURE_DATA  ( I, J )                          ;
     COMPUTE_PLANETOCENTRIC_ARRIVAL_DATA    ( I, J )                          ;


pragma page ;


     exception
     when TOO_FAST =>
          for KIND in DATA_KIND loop
               DVALUE( KIND )(I,J) :=  10001                                  ;
               end loop                                                       ;
     when TOO_HOT  =>
          for KIND in MULTIREV_SEMIMAJOR_AXIS..APHELION_DISTANCE loop
               DVALUE( KIND )(I,J) :=  10002                                  ;
               end loop                                                       ;
     when LAMBERT_Z_ITERATION_FAILED_TO_CONVERGE =>
          for KIND in MULTIREV_SEMIMAJOR_AXIS..APHELION_DISTANCE loop
               DVALUE( KIND )(I,J) :=  10003                                  ;
               end loop                                                       ;
     when LAMBERT_CANNOT_ATTAIN_SPECIFIED_NUMBER_OF_REVS =>
          for KIND in MULTIREV_SEMIMAJOR_AXIS..APHELION_DISTANCE loop
               DVALUE( KIND )(I,J) :=  10004                                  ;
               end loop                                                       ;

     end                                                                      ;
```

FIG. 1.3.23

All exceptions are handled within the same module where the exception is raised. For example , consider the newly created procedure EXCEPTION_HANDLER_10001. The exception is raised if the absolute value of TF_DAYS is less than or equal to 20.0. The module is reengineered in such a way that the sequence of instructions that are to be executed the moment this execption is raised are within the same procedure itself. This is illustrated in FIG. 1.3.24.

```
Procedure EXCEPTION_HANDLER_10001(TF_DAYS : flote; DONE : boolean; NAME : in
                             APPLICATION_TYPE; CATEGORY : CATEGORY_TYPE) IS

Begin
   if NAME = POWRSWNG then
     if CATEGORY = LEG1 then
       TF_days := flote(Jdate(SWBY) - JDATE(HOME));
         if abs(TF_DAYS) <= 20.0 then
             for kind1 in LEG1_HELIOCENTRIC_TRANSFER_ANGLE..LEG1_FLIGHT_TIME loop
               VALUE1(KIND1)(J) := 10001;
            end loop;
         end if;
        DONE := true;
     elsif CATEGORY = LEG2 then
       TF_days := flote(Jdate(TRAJ) - JDATE(SWBY));
         if abs(TF_DAYS) <= 20.0 then
```

```
            for kind1 in LEG2_HELIOCENTRIC_TRANSFER_ANGLE..LEG2_FLIGHT_TIME loop
             VALUE2(KIND2)(I,J) := 10001;
            end loop;
         end if;
        DONE := true;
     end if;

   else
    TF_days := flote(Jdate(TRAG) - JDATE(HOME));
     if abs(TF_DAYS) <= 20.0 then
          for kind in DATA_KIND loop
            DVALUE(KIND)(I,J) := 10001;
          end loop;
        DONE := true;
     end if;
   end if;
  end EXCEPTION_HANDLER_10001;
```

FIG. 1.3.24

The variable TF_DAYS should be passed-in from the module COMPUTE_TRAJECTORY_DATA because it is declared inside that module. Moreover, three new parameters NAME_IN, CATEGORY and a boolean variable DONE are passed into the module. CATEGORY is of user defined type CATEGORY_TYPE and have elements (LEG1 and LEG2).

In the original code of this module, once the exception is raised, the execution is passed to the area where the exception is defined. Once that area is executed, the control will transferred to the end of the module. In the reengineered module, this is handled by a if-then-else structure. We have selected to introduce an if-then-else structure because ESL supports such structures. Hence the reengineered procedure COMPUTE_TAJECTORY_DATA will have the following format and is a sub program within ESL requirements.

```
procedure COMPUTE_TRAJECTORY_DATA ( I, J : integer ) is


          SINFAC       : FLOTE  ;
          TEST_VEC     : VECTOR ;
          TF_DAYS      : FLOTE  ;
          DONE_1, DONE_2, DONE_3 : boolean := false;
          DESTINATION_D : DESTINATION_TYPE := DEPARTURE;
          DESTINATION_A : DESTINATION_TYPE:= ARRIVAL;
          NAME : APPLICATION_TYPE:= INTRPLEC;
          CATEGORY := DUMMY;

begin
 EXCEPTION_HANDLER_10001(TF_DAYS,DONE_1, NAME , CATEGORY);
 if DONE_1 = false then
  CALCULATIONS(TF_DAYS, SINFAC, TEST_VEC);
  FIND_BEST_TRANSFER_TRAJECTORY;
  CALL_FOR_EXCEPTION_HANDLER_10003_10004(DONE_2,CATEGORY,NAME);
```

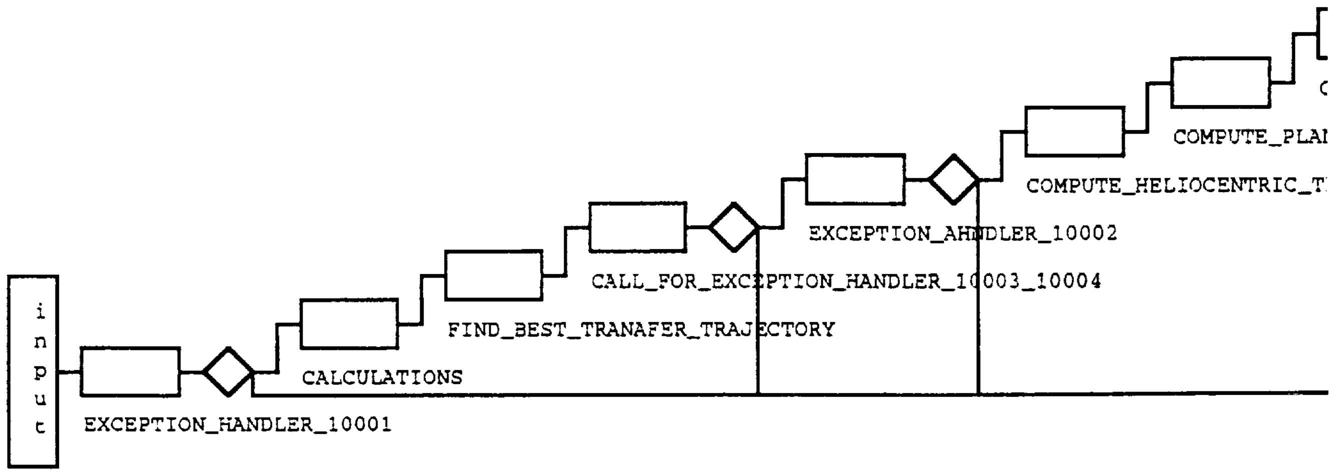
```
   if DONE_2 = false then
     EXCEPTION_HANDER_10002(DONE_3, NAME);
     if DONE_3 = true then
       COMPUTE_HELIOCENTRIC_TRAJECTORY_DATA( I, J, NAME );
       COMPUTE_PLANETOCENTRIC_ARRIVAL_OR_DEPARTURE_DATA(I, J, DESTINATION_D, NAME);
       COMPUTE_PLANETOCENTRIC_ARRIVAL_OR_DEPARTURE_DATA(I, J, DESTINATION_A, NAME )
     end if;
   end if;
  end if;
end COMPUTE_TRAJECTORY_DATA;
```

FIG.1.3.25

The corresponding ESL object graph diagram for the above sub program is shown in fig. 1.3.26.

FIG . 1.3.26

ESL OBJECT DIAGRAM FOR THE SUB PROGRAM COMPUTE_TRAJECT



The ESL object graphs of the same sub program in BEST1WAY and POWRSWNG are slightly different to the above. The graph shown above is the ESL object graph for INTRPLAN. The ESL object graph for IPCAPTUR is almost the same except for less one procedure call(i.e exception_handler_10002).

In the original program code for the procedure COMPUTE_TRAJECTORY_DATA, we see two procedure calls by the names COMPUTE_PLANETOCENTRIC_DEPARTURE_DATA and COMPUTE_PLANETOCENTRIC_ARRIVAL_DATA. Since the two procedures do the same task, we could have one procedure to handle both situations and building another reusable module.

```
procedure COMPUTE_PLANETOCENTRIC_DEPARTURE_DATA ( I,J : integer ) is

          DECL   : integer ;
          DELV   : FLOTE   ;
          DV     : integer ;
          RASC   : integer ;
          VINHAT : VECTOR  ;
          VINMAG : FLOTE   ;
          VINVEC : VECTOR  ;
          VINF   : integer ;


     begin
     VINVEC := (XFR_HELIVEL(DEP)-HELIVEL(DEP))*VBASE_M50_E(DEP)                    ;
     VINMAG :=  ABS( VINVEC )                                                      ;
     VINHAT :=  VINVEC / VINMAG                                                    ;
     DELV   :=  DEPARTURE_VELOCITY_INCREMENT                                       ;
     DV     :=  DATA_MATRIX_INTEGER(      DELV         *  100      )               ;
     VINF   :=  DATA_MATRIX_INTEGER(      VINMAG       *  100      )               ;
     DECL   :=  ROUND( ASIN ( VINHAT(3)            ) * 1800 / PI )                 ;
     RASC   :=  ROUND( ATAN1( VINHAT(2) , VINHAT(1) ) * 1800 / PI )                ;
     DVALUE( NOMINAL_DEPARTURE_DELTA_V         )(I,J) :=   DV      ; --  dkm/sec
     DVALUE( DEPARTURE_V_INFINITY_MAGNITUDE    )(I,J) :=  VINF     ; --  dkm/sec
     DVALUE( DEPARTURE_V_INFINITY_DECLINATION )(I,J) :=  DECL     ; --  0.1 deg
     DVALUE( DEPARTURE_V_INFINITY_RTASCENSION )(I,J) :=  RASC     ; --  0.1 deg
     end ;
```

FIG. 1.3 27

```
procedure COMPUTE_PLANETOCENTRIC_ARRIVAL_DATA ( I,J : integer ) is

          DECL   : integer ;
          RASC   : integer ;
          VINHAT : VECTOR  ;
          VINMAG : FLOTE   ;
          VINVEC : VECTOR  ;
          VINF   : integer ;
          SPEED  : FLOTE   ;
          SPD    : integer ;


     begin
     VINVEC := (XFR_HELIVEL(ARR)-HELIVEL(ARR))*VBASE_M50_E(ARR)                    ;
     VINMAG :=  ABS( VINVEC )                                                      ;
     VINHAT :=  VINVEC / VINMAG                                                    ;
```

```
SPEED   :=  SQRT( VESQ(ARR) + VINMAG*VINMAG )                              ;
SPD     :=  DATA_MATRIX_INTEGER(            SPEED       *  100      )      ;
VINF    :=  DATA_MATRIX_INTEGER(            VINMAG      *  100      )      ;
DECL    :=  ROUND(         ASIN  ( VINHAT(3)            ) * 1800 / PI )    ;
RASC    :=  ROUND(         ATAN1( VINHAT(2) , VINHAT(1) ) * 1800 / PI )    ;
DVALUE( ARRIVAL_SPEED                      )(I,J) :=    SPD        ; -- dkm/sec
DVALUE( ARRIVAL_V_INFINITY_MAGNITUDE       )(I,J) :=   VINF        ; -- dkm/sec
DVALUE( ARRIVAL_V_INFINITY_DECLINATION     )(I,J) :=   DECL        ; -- 0.1 deg
DVALUE( ARRIVAL_V_INFINITY_RTASCENSION     )(I,J) :=   RASC        ; -- 0.1 deg
end                                                                        ;
```

FIG. 1.3.28

```
procedure COMPUTE_PLANETOCENTRIC_ARRIVAL_OR_DETARTURE_DATA ( I,J: integcr;
                                                     DESTINATION : DESTINATION_TYPE;
                                                     NAME: APPLICATION_TYPE) is

DECL : integer;
RASC : integer;
VINHAT: VECTOR;
VINMAG: FLOTE;
VINVEC: VECTOR;
VINF : integer;
DV_OR_SPD : integer;
TEMP: TRAJ_NODE;
NDDV_OR_AS: ;
DVIM_OR_AVIM: ;
DVID_OR_AVID: ;
DVIR_OR_AVIR;
TOT_DELV: flote;
TOT_DV : integer;

begin
 case DESTINATION is
   when DEPARTURE | departure => TEMP := DEP;
   when ARRIVAL | arrival     => TEMP := ARR;
 end case;

VINVEC := (XFR HELIVEL(TEMP)- HELIVEL(TEMP))*VBASE M50 E(TEMP);
VINMAG := ABS( VINVEC ) ;
VINHAT := VINVEC / VINMAG;
if DESTINATION = DEPARTURE then
    DELV OR SPEED := DEPARTURE VELOCITY INCREMENT;
     if NAME = IPCAPTURE then
        TOT_DELV := ARRIVAL_VELOCITY_INCREMENT + DELV_OR_SPEED;
        TOT_DV := DATA_MATRIX_INTEGER(TOT_DEV * 100);
     end if;

    NDDV_OR_AS    := NOMINAL_DEPARTURE DELTA_V;
    DVIM_OR_AVIM  := DEPARTURE_V_INFINITY_MAGNITUDE;
    DVID_OR_AVID  := DEPARTURE_V_INFINITY_DECLINATION;
    DVIR_OR_AVIR  := DEPARTURE_V_INFINITY_RTASCENSION;
elsif DESTINATION = ARRIVAL then
    DELV_OR_SPEED := SQRT(VESQ(TEMP) + VINMEG*V-MEG);
    DELV_OR_SPEED := MIN ( DELV_OR_SPEED , MAXAVELMAG(TEMP);
    NDDV_OR_AS := ARRIVAL_SPEED;
    DVIM_OR_AVIM := ARRIVAL_V_INFINITY_MAGNITUDE;
    DVID_OR_AVID := ARRIVAL_V_INFINITY_DECLINATION;
    DVIR_OR_AVIR := ARRIVAL_V_INFINITY_RTASCENSION;
end if;

    DV_OR_SPD := DATA_MATRIX_INTEGER( DELV_OR_SPEED * 100);
    VINF := DATA_MATRIX_INTEGER(VINMAG * 100);
    DECL := ROUND(ASIN ( VINHAT(3)      ) * 1800/ PI ) ;
    RASC := ROUND(    ATANI( VINHAT(2), VINHAT(I) ) * 1800 / PI );
    if NAME := IPCAPTURE then
       DVALUE( NDDV_OR_AS )(I,J) := DV_OR_SPD ; -- dkrn/sec
       DVALUE( NDDV_OR_AS )(I,J) := DV_OR_SPD ; -- dkrn/sec
       DVALUE( DVIM_OR_AVIM )(I,J) := VINF ; -- dkrn/sec
       DVALUE( DVID_OR_AVID )(I,J) := DECL ; -- 0.1 deg
       DVALUE( DVIR_OR_AVIR )(I,J) := RASC ; -- 0.1 deg
    end if
end;
```

FIG. 1.3.29

The figures 1.3.27 and 1.3.28 show the two procedures in question. Fig. 1.3.29 is the modified procedure built to represent both the procedures shown in figures 1.3.27 and 1.3.28. This procedure replaces 8 modules in all four applications. And hence, it is reusable. In order to make this a reusable module, new variables have been introduced along with the necessary modifications. This procedure also resides in the package common_modules which is designed to reside all the newly created, and modified modules.

Procedure COMPUTE_TRAJECTORY_FOR_FIRST_HELIOCENTRIC_LEG, and COMPUTE_TRAJECTORY_FOR_SECOND_HELIOCENTRIC_LEG are available only in applications BEST1WAY and POWRSWNG. However the procedure in POWRSWNG is very similar to the procedure COMPUTE_TRAJECTORY_DATA in INTRPLAN & IPCAPTURE. Hence this procedure in POWRSWNG can be replaced by already designed reusable components and made a seperate ESL object graph (see FIG. 1.2.   ). But as we have done in earlier cases, these two procedures in BEST1WAY have been modified and built one single reusable procedure named COMPUTE_TRAJECTORY_FOR_FIRST_AND_SECOND_HELIOCENTRIC_LEG. The following figures show the modifications.

```
procedure COMPUTE_TRAJECTORY_FOR_FIRST_HELIOCENTRIC_LEG is


      ANGMO_PREF : VECTOR ;
      TF1_DAYS   : FLOTE  ;
      TF1_SECS   : FLOTE  ;


    begin
   TF1_DAYS := FLOTE( JDATE(SWBY) - JDATE(DEP) )               ;
   TF1_SECS := 86400.0 * TF1_DAYS                       ;
   ANGMO_PREF := HELIPOS(DEP) * HELIVEL(DEP)                ;
   SOLVE_LAMBERT_PROBLEM ( HELIPOS(DEP), TF1_SECS, HELIPOS(SWBY),
ANGMO_PREF,
                  XFR_HELIVEL(DEP),     XFR_HELIVEL(SWBY), GM_SUN   );
   ANTE_SWBY_VINVEC := XFR_HELIVEL(SWBY) - HELIVEL(SWBY)           ;
   end                                              ;
```

FIG. 1.3.31

```
procedure COMPUTE_TRAJECTORY_FOR_SECOND_HELIOCENTRIC_LEG is


      ANGMO_PREF : VECTOR ;
      TF2_DAYS   : FLOTE ;
      TF2_SECS   : FLOTE ;


    begin
   TF2_DAYS := FLOTE( JDATE(ARR) - JDATE(SWBY) )                    ;
   TF2_SECS := 86400.0 * TF2_DAYS                              ;
   ANGMO_PREF := HELIPOS(ARR) * HELIVEL(ARR)                        ;
   SOLVE_LAMBERT_PROBLEM ( HELIPOS(SWBY), TF2_SECS, HELIPOS(ARR),
ANGMO_PREF,
               XFR_HELIVEL(SWBY),    XFR_HELIVEL(ARR), GM_SUN    );
   POST_SWBY_VINVEC := XFR_HELIVEL(SWBY) - HELIVEL(SWBY)                ;
   end                                              ;
```

FIG. 1.3.32

The following is the modified version of the above two modules.

```
procedure COMPUTE_TRAJECTORY_FOR_FIRST_AND_SECOND_HELIOCENTRIC_LEG(CATEGORY :
                                                        CATEGORY_TYPE) is

-- THIS IS A REUSABLE COMMON MODULE FOR COMPUTE_TRAJECTORY_FOR_FIRST_HELIOCENTRIC_LEG
--& COMPUTE_TRAJECTORY_FOR_SECOND_HELIOCENTRIC_LEG --
-- CHANGES HAVE BEEN MADE ACCORDINGLY.

          ANGMO_PREF : VECTOR ;
          TF1_DAYS   : FLOTE  ;

  begin
     if CATEGORY = LEG1 then
       TF1_DAYS :=  FLOTE( JDATE(SWBY) - JDATE(DEP) )                     ;
       ANGMO_PREF :=  HELIPOS(DEP) * HELIVEL(DEP)                         ;

       SOLVE_LAMBERT_PROBLEM (HELIPOS(DEP), TF1_DAYS* 86400.0, HELIPOS(SWBY),
              ANGMO_PREF, XFR_HELIVEL(DEP),  XFR_HELIVEL(SWBY), GM_SUN    );
              ANTE_SWBY_VINVEC :=  XFR_HELIVEL(SWBY) - HELIVEL(SWBY)      ;


     else
       TF1_DAYS :=  FLOTE( JDATE(ARR) - JDATE(SWBY) )                     ;
       ANGMO_PREF :=  HELIPOS(ARR) * HELIVEL(ARR)                         ;

       SOLVE_LAMBERT_PROBLEM ( HELIPOS(SWBY), TF1_DAYS * 86400.0 , HELIPOS(ARR),
           ANGMO_PREF, XFR_HELIVEL(SWBY),      XFR_HELIVEL(ARR), GM_SUN    );
           POST_SWBY_VINVEC :=  XFR_HELIVEL(SWBY) - HELIVEL(SWBY)              ;
     end if;
  end                                                             ;
```

1.3.5 Application BEST1WAY

A few modules in BEST1WAY do not match with any of the modules in either POWRSWNG or INTRPLAN or IPCAPTUR. These modules canot be made reusable because they are unique only to BEST1WAY. Therefore the following modules remain same in the application BEST1WAY.

FIND_BEST_DIRECT_TRANSFER_TRAJECTORY
FIND_BEST_SWING_BY_TRAJECTORY
ISOLATE_UNPOWERED_SWINGBY_SOLUTION
COMPUTE_PLANETOCENTRIC_SWINGBY_TRAJECTORY_DATA

1.3.6 Application POWRSWNG

As in BEST1WAY, POWRSWNG also has a few unique modules that are used nowhere else. Since these modules cannot be made reusable, they remain unchanged within the application itself. Hence the modules

COMPUTE_LEG1_PLANETOCENTRIC_TRAJECTORY_DATA
COMPUTE_LEG2_PLANETOCENTRIC_TRAJECTORY_DATA
COMPUTE_PLANETOCENTRIC_SWINGBY_TRAJECTORY_DATA

remain unchanged.

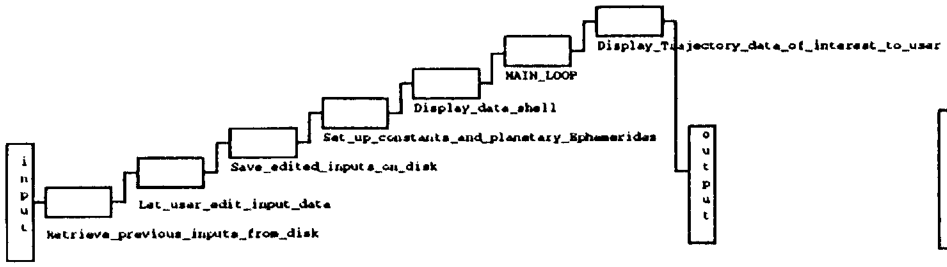
1.3.7 Module DATA_MATRIX_INTEGER

Module DATA_MATRIX_INTEGER is one common module found in all four applications. This module can be used in all applications without any modifications. Therefore this module has been shifted into the package COMMON_MODULES where all the reusable common modules reside.

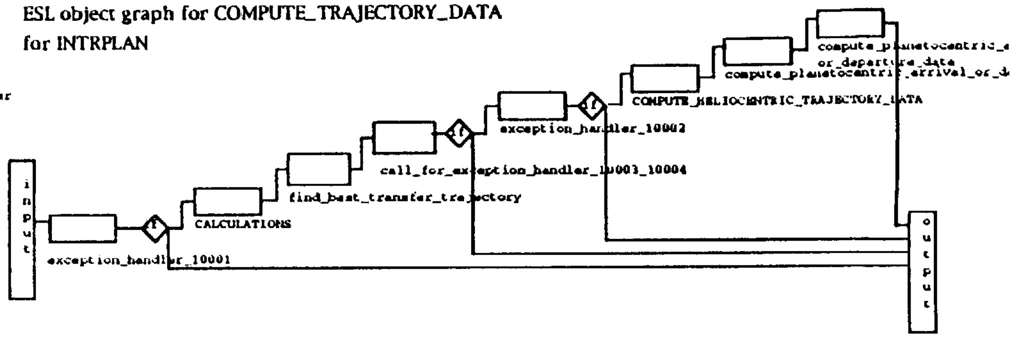
1.3.8 Complete ESL object graphs for all four applications.

This section provides full ESL object graphs for all four applications.

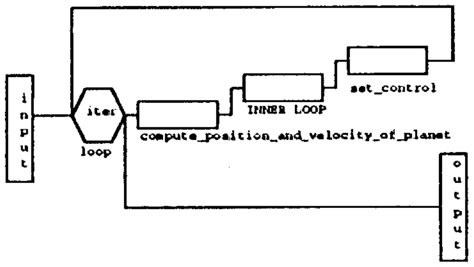
ESL Object graph for main program of INTRPLAN


input
Retrieve_previous_inputs_from_disk
Let_user_edit_input_data
Save_edited_inputs_on_disk
Set_up_constants_and_planetary_Ephemerides
Display_data_shell
MAIN_LOOP
Display_Trajectory_data_of_interest_to_user
output

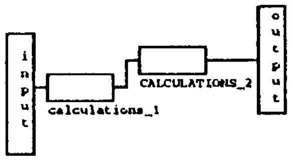
ESL object graph for COMPUTE_TRAJECTORY_DATA for INTRPLAN


input
exception_handler_10001
CALCULATIONS
find_best_transfer_trajectory
call_for_exception_handler_10003_10004
exception_handler_10002
COMPUTE_HELIOCENTRIC_TRAJECTORY_DATA
compute_planetocentric_arrival_or_d
compute_planetocentric_
or_departure_data
output

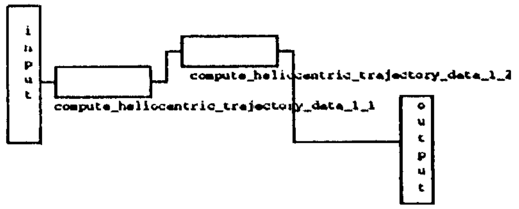
The ESL object graph for subprogram MAIN_LOOP



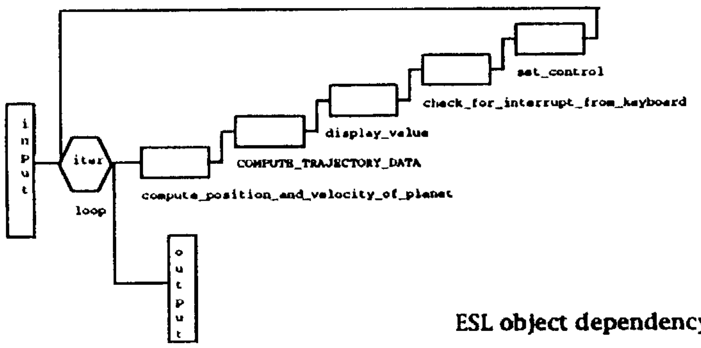
ESL object graph for subprogram CALCULATIONS



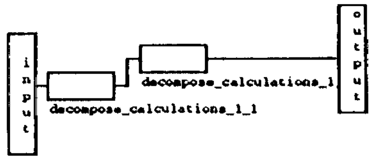
ESL object graph for COMPUTE_HELIOCENTRIC_TRAJECTORY_DATA


input
compute_heliocentric_trajectory_data_1_1
compute_heliocentric_trajectory_data_1_2
output

The ESL object graph for subprogram INNER_LOOP

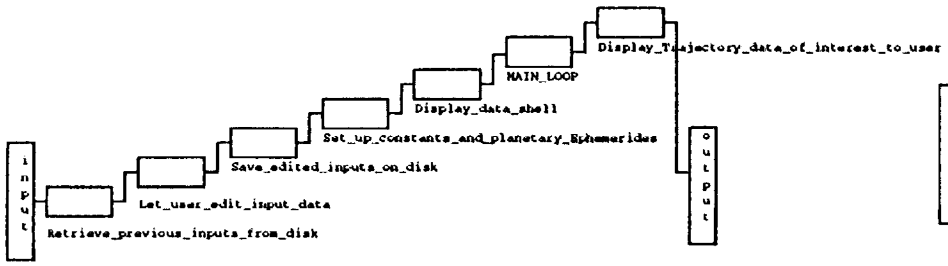

input
iter
loop
compute_position_and_velocity_of_planet
COMPUTE_TRAJECTORY_DATA
display_value
check_for_interrupt_from_keyboard
set_control
output

ESL object graph for subprogram CALCULATIONS_2

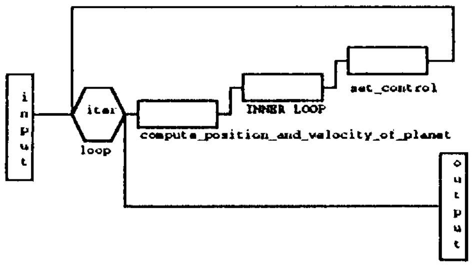


ESL object dependency graph for INTRPLAN

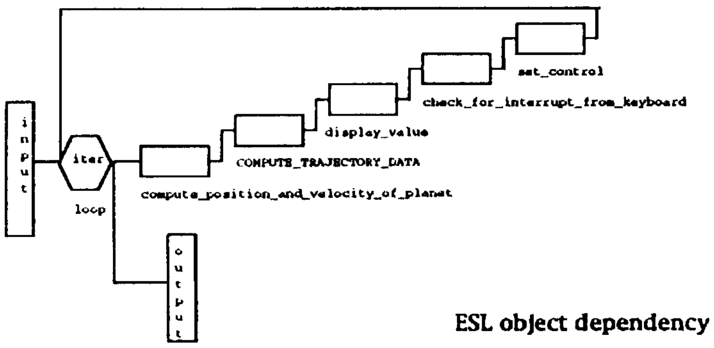
ESL Object graph for main program of IPCAPTUR


input
Retrieve_previous_inputs_from_disk
Let_user_edit_input_data
Save_edited_inputs_on_disk
Set_up_constants_and_planetary_Ephemerides
Display_data_shell
MAIN_LOOP
Display_Trajectory_data_of_interest_to_user
output

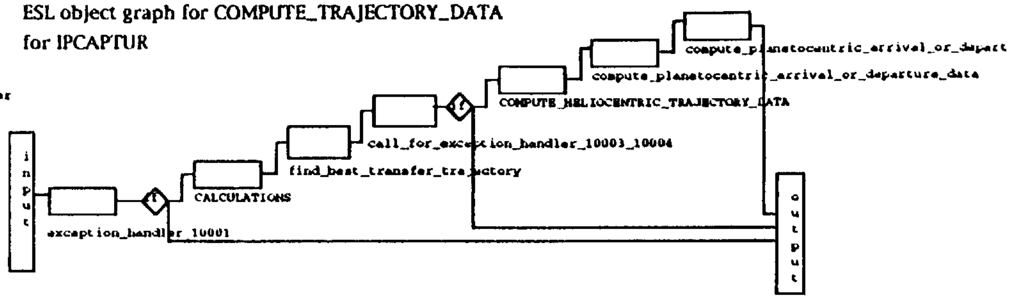
The ESL object graph for subprogram MAIN_LOOP



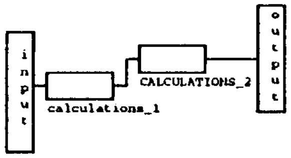
The ESL object graph for subprogram INNER_LOOP


input
iter
loop
compute_position_and_velocity_of_planet
COMPUTE_TRAJECTORY_DATA
display_value
check_for_interrupt_from_keyboard
set_control
output

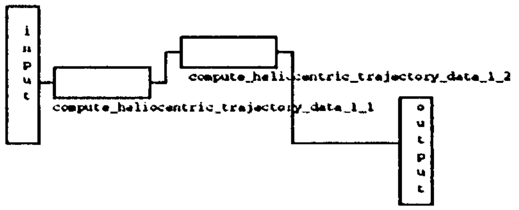
ESL object graph for COMPUTE_TRAJECTORY_DATA for IPCAPTUR


input
exception_handler_10001
CALCULATIONS
find_best_transfer_trajectory
call_for_exception_handler_10003_10004
COMPUTE_HELIOCENTRIC_TRAJECTORY_DATA
compute_planetocentric_arrival_or_departure_data
compute_planetocentric_arrival_or_depart
output

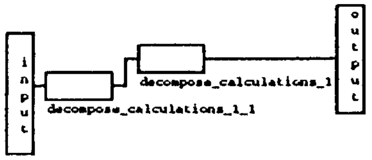
ESL object graph for subprogram CALCULATIONS



ESL object graph for COMPUTE_HELIOCENTRIC_TRAJECTORY_DATA

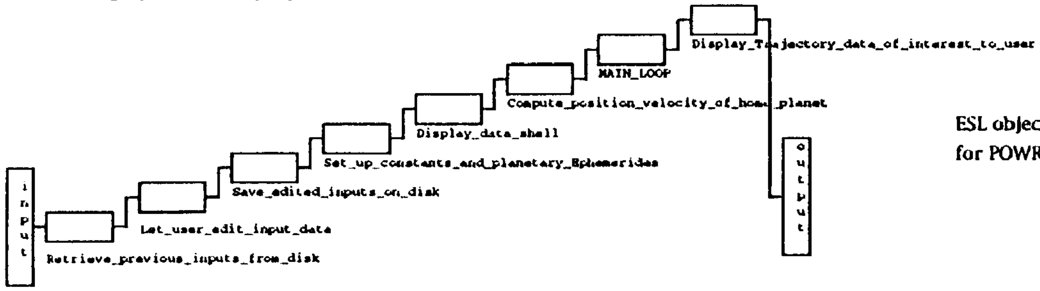

input
compute_heliocentric_trajectory_data_1_1
compute_heliocentric_trajectory_data_1_2
output

ESL object graph for subprogram CALCULATIONS_2

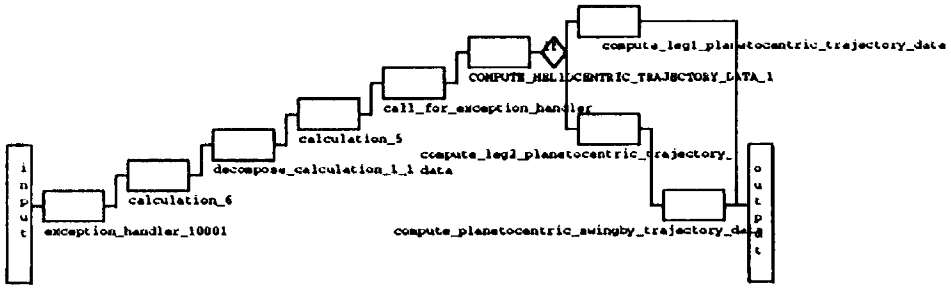


ESL object dependency graph for IPCAPTUR

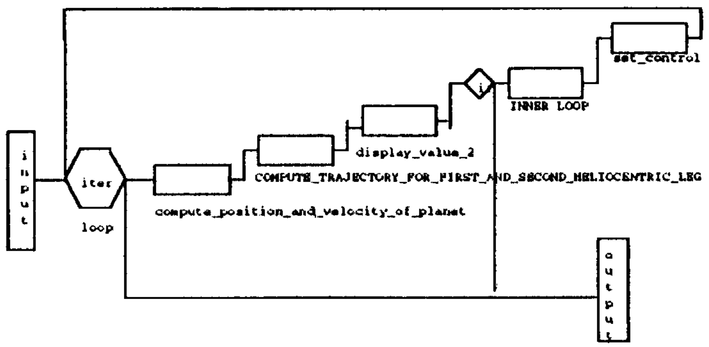
ESL Object graph for main program of POWRSWNG


input
Retrieve_previous_inputs_from_disk
Let_user_edit_input_data
Save_edited_inputs_on_disk
Set_up_constants_and_planetary_Ephemerides
Display_data_shell
Compute_position_velocity_of_home_planet
MAIN_LOOP
Display_Trajectory_data_of_interest_to_user
output

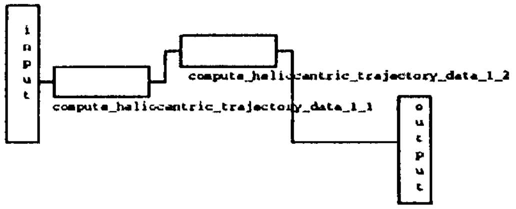
ESL object graph for COMPUTE_TRAJECTORY_FOR_FIRST_AND_SECOND_HELIOCENTRIC_LEG for POWRSWNG


input
exception_handler_10001
calculation_6
decompose_calculation_1_1 data
calculation_5
call_for_exception_handler
COMPUTE_HELIOCENTRIC_TRAJECTORY_DATA_1
compute_leg1_planetocentric_trajectory_data
compute_leg2_planetocentric_trajectory_
compute_planetocentric_swingby_trajectory_data
output

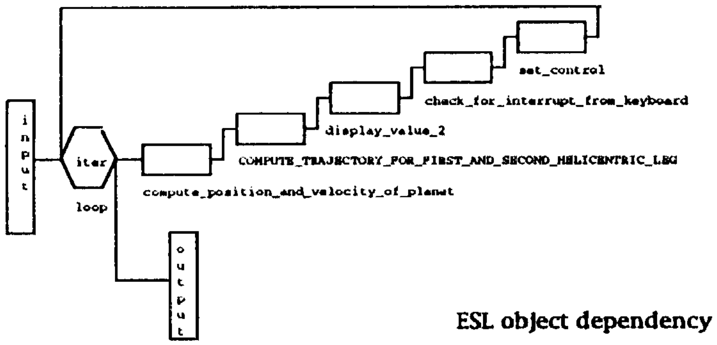
The ESL object graph for subprogram MAIN_LOOP


input
iter
loop
compute_position_and_velocity_of_planet
COMPUTE_TRAJECTORY_FOR_FIRST_AND_SECOND_HELIOCENTRIC_LEG
display_value_2
INNER LOOP
set_control
output

ESL object graph for COMPUTE_HELIOCENTRIC_TRAJECTORY_DATA_1

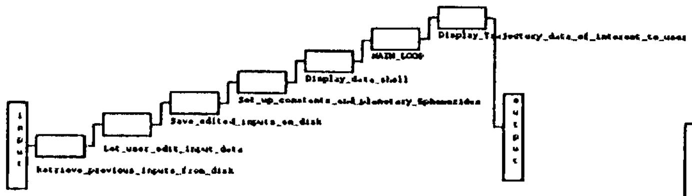

input
compute_heliocentric_trajectory_data_1_1
compute_heliocentric_trajectory_data_1_2
output

The ESL object graph for subprogram INNER_LOOP

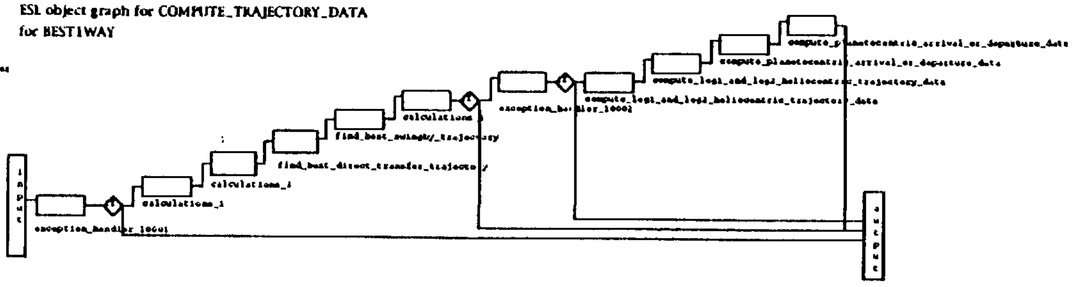

input
iter
loop
compute_position_and_velocity_of_planet
COMPUTE_TRAJECTORY_FOR_FIRST_AND_SECOND_HELICENTRIC_LEG
display_value_2
check_for_interrupt_from_keyboard
set_control
output

ESL object dependency graph for POWRSWING

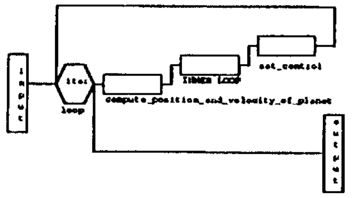
ESL Object graph for main program of BEST1WAY


input
retrieve_previous_inputs_from_disk
Let_user_edit_input_data
Save_edited_inputs_on_disk
Set_up_constants_and_planetary_Ephemerides
Display_data_shell
MAIN_LOOP
Display_trajectory_data_of_interest_to_user
output

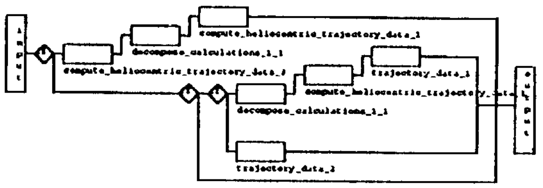
ESL object graph for COMPUTE_TRAJECTORY_DATA
for BEST1WAY


input
exception_handler_1000
calculations_1
calculations_1
find_best_direct_transfer_trajectory
find_best_swingby_trajectory
calculations_1
exception_handler_1000
compute_leg1_and_leg2_heliocentric_trajectory_data
compute_leg1_and_leg2_heliocentric_trajectory_data
compute_planetocentric_arrival_or_departure_data
compute_planetocentric_arrival_or_departure_data
output

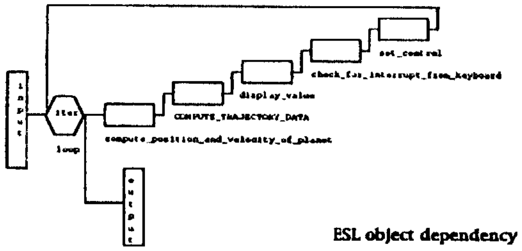
The ESL object graph for subprogram MAIN_LOOP



ESL object graph for COMPUTE_LEG1_AND_LEG2_HELIOCENTRIC_TRAJECTORY_DATA
for BEST1WAY


input
compute_heliocentric_trajectory_data_1
decompose_calculations_1_1
compute_heliocentric_trajectory_data_1
trajectory_data_1
compute_heliocentric_trajectory_data
decompose_calculations_1_1
trajectory_data_2
output

The ESL object graph for subprogram INNER_LOOP


input
iter
loop
compute_position_and_velocity_of_planet
COMPUTE_TRAJECTORY_DATA
display_values
check_for_interrupt_from_keyboard
set_control
output

ESL object dependency graph for BEST1WAY

2. Lessons Learned About Current ESL Tool

CBR matching window will not help us retrieve components - only the class structure helps.

Component attributes describing the components are not sufficient now; particularly, there are no slots for the purpose of the components.

ESL graphs are similar to DFDs with control flows, but have at least 2 additional constructs: loop and if-then.

Does not address at all the library functions, CM functions, IV & V functions.

Standards for components ? How can we make a reusable component? Domain oriented vs. Computer-Science oriented components.

No facilities for FOR loops except for WHILE loops.

In the ESL system, the looping structures are restricted only to while loops. This is a severe draw back. It was found that , during the reengineering process, all the FOR loops in subprograms had to be changed into while loops. In order to do this more modules had to be created. One example is an unnecessary module has to be created to increment the iterated value for the WHILE loop. But if there were facilities to implement FOR loops, this unnecessary creation of modules could have been avoided.

Lack of labelling the ESL graph.

Another shortcoming found in the ESL graphs was that the lack of directional labelling. For example, in an if node, we know that there are two dirctions, one for THEN and the other for ELSE. The graph does not show this, and the reader would not know which one is THEN and which one is ELSE. A situation like this would put the reader into confusion.

*** FIRST DRAFT ***

Syntax errors found in generated Ada code.

A few serious syntax errors were found in the generated Ada code.

Errors:

1. When already existing graph is modified, it won't allow you to exit the sytem without saving it. If you select the delete option, it will erase the graph from the knowledge base butthe drawing file.dwg will still exist.

2. Cannot resize the graph editor panel.

3. Connector drawing algorithm too simple. Needs improvements. Multiple link.
4. Drawing files may not be consistent with the knowledge base.

5. When a node is deleted on the drawing panel, still that object is shown on "Node on graph" pannel.